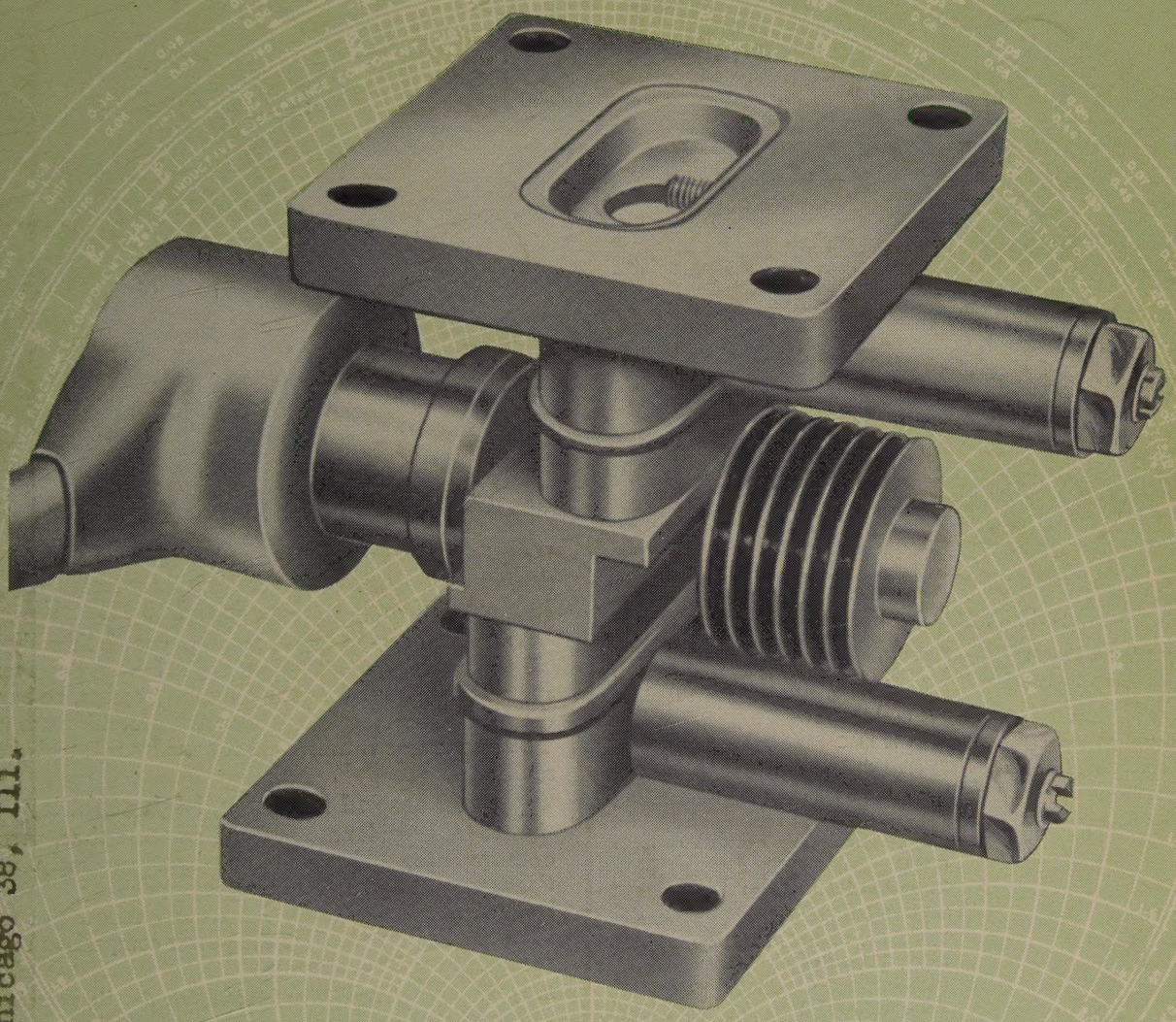
APRIL 1959
VOL. 2 • NO. 4

- Jones & Lowrey — Plasma Resonance Scanners
- Rockwell — New Klystron Amplifier
- Saul & Luloff — Noise Figure Measurements
- Company Profile — Raytheon, Part II

the microwave journal



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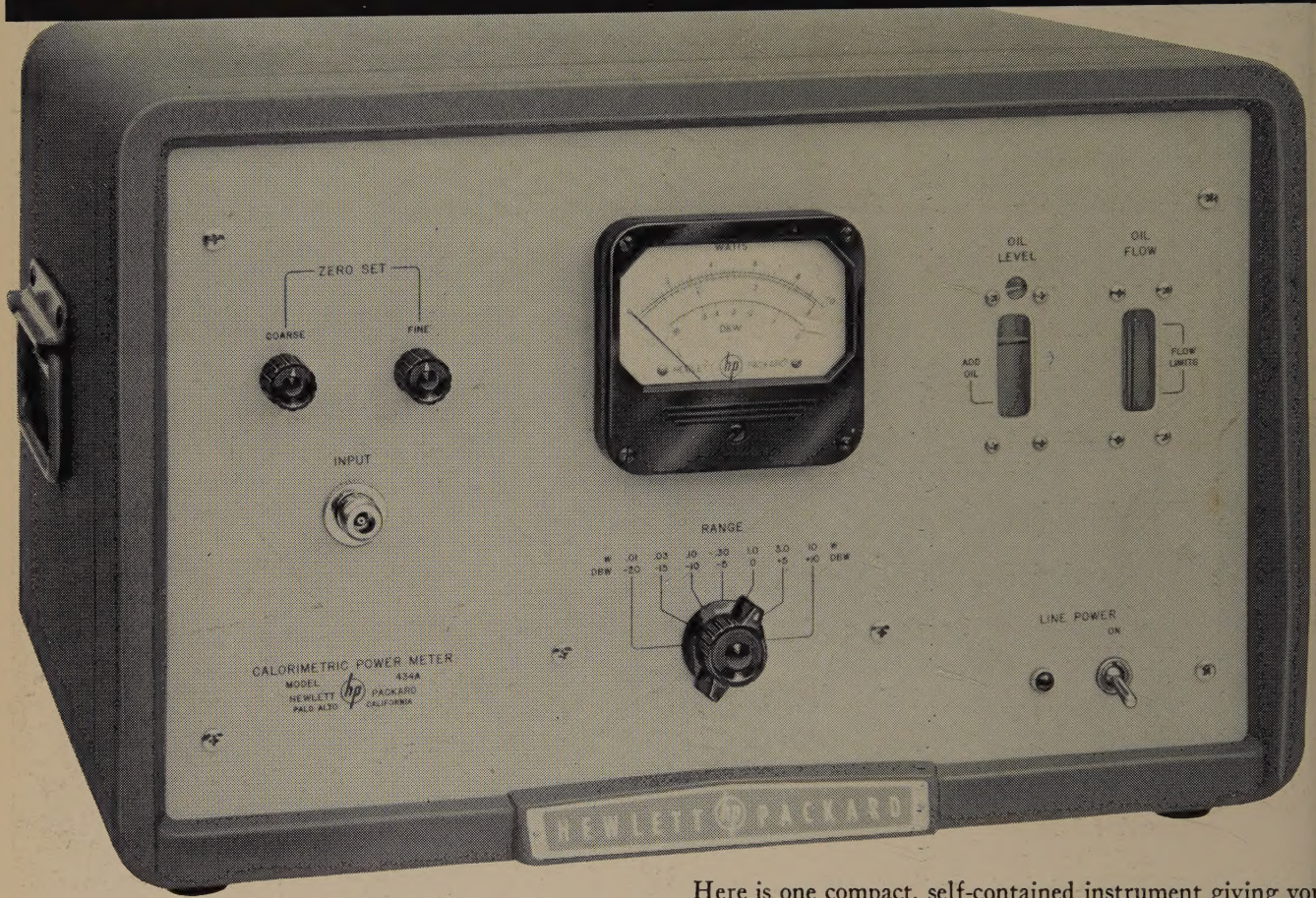

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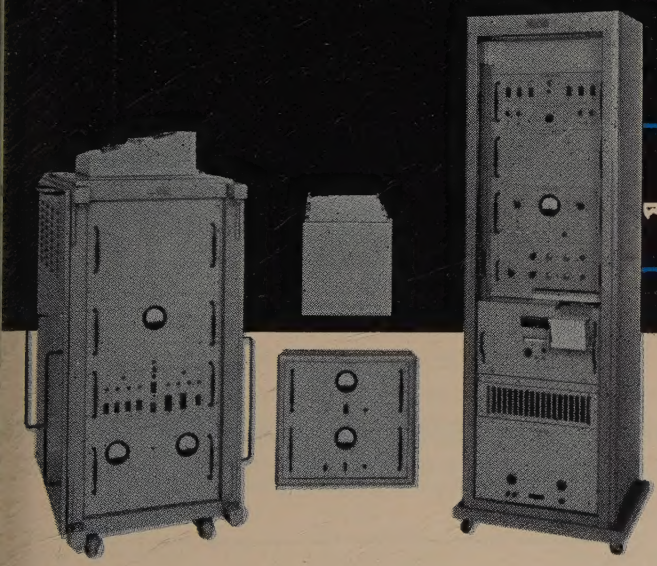

Maximum antenna temperature for this observation: 0.04° Kelvin
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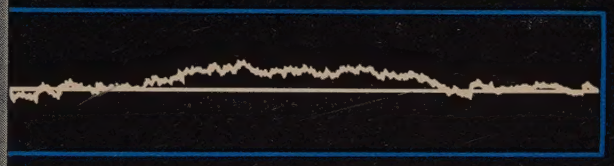

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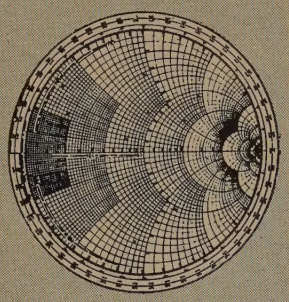

the microwave journal

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COVER PICTURE
(Courtesy of Varian Associates)

A hermetically sealed VA-824, now in service in a high altitude doppler navigator. Details of the development of this externally tuned 2-watt amplifier are described in this issue beginning on page 27.

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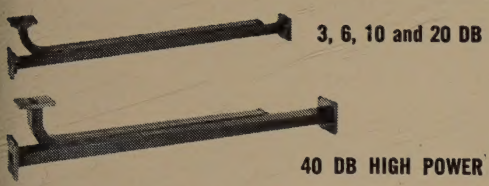
XN	5.40-8.20	1½ x ¾	1032	255.
XB	7.05-10.0	1¼ x ⅝	1031	220.
X	8.20-12.4	1 x ½	1030	175.
KU	12.4-18.0	.702 x .391	1029	180.
K	18.0-26.5	½ x ¼	1028	295.
V	26.5-40.0	.360 x .220	V1027	330.
M	50.0-75.0	.228 x .154	M1027	900.



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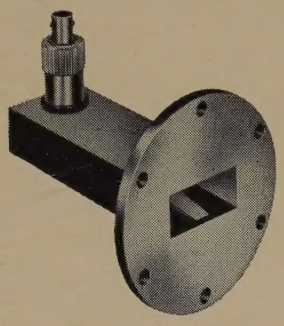

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LS	1.70-2.60	4.46x2.31	535	BOLOMETER N-605 THERMISTOR N-333D	1.35 1.5	IN21 or IN23	9	210.
S	2.60-3.95	3x1½	534	BOLOMETER N-605 THERMISTOR N-333D	1.35 1.5	IN21 or IN23	7¾	110.
C	3.95-5.85	2x1	533	BOLOMETER N-605 THERMISTOR N-333D	1.5 1.5	IN21 or IN23	5⅜	80.
XN	5.40-8.20	1½x¾	532	BOLOMETER N-605	1.5	IN23	4⅛	90.
			542	THERMISTOR N-333D	1.5	1N23	4 1/16	75.
XB	7.05-10.0	1¼x⅝	531	BOLOMETER N-605	1.5	1N23	3¼	85.
			541	THERMISTOR N-333D	1.5	1N23	3¼	65.
X	8.20-12.4	1x½	530	BOLOMETER N-604	1.5		2⅜	65.
			540	THERMISTOR N-336	1.5		2¼	60.
KU	12.4-18.0	.702x.391	529	BOLOMETER N-604	1.5		2	65.
			539	THERMISTOR N-336	1.75		2¼	95.
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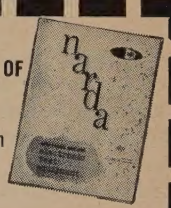

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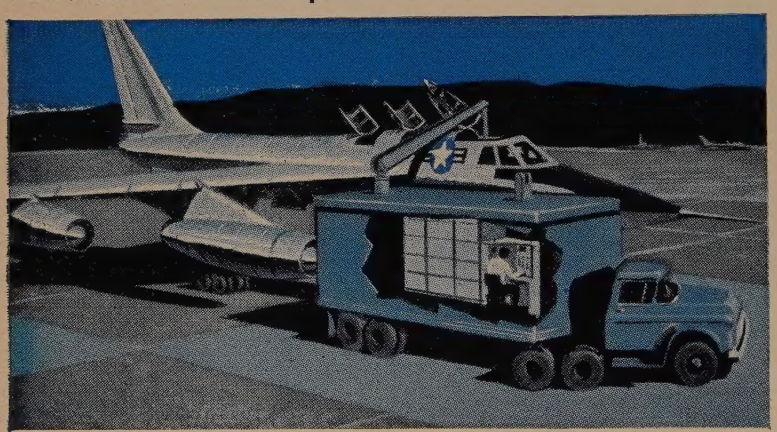

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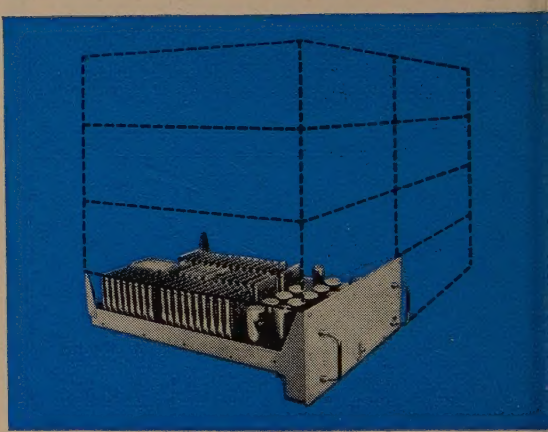

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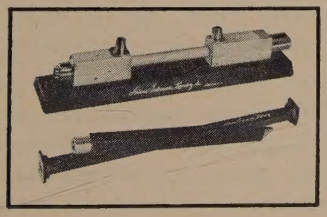

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WHEN IS AN ENGINEER?

Marshall C. Pease

Sylvania Electric Products, Inc

AN ENGINEER, it is usually conceded, especially by engineers, is a useful fellow to have around. He is the guy you look to to tell you how to make something. So maybe it turns out there are still problems, even after you have made use of all the engineer's suggestions. You know that if you ask him, he will have more answers, and that eventually, you will either make money or go out of business.

A scientist, of course, is the white hope of the future. Out of his shrouded laboratories are going to come those magic runes known as "facts of nature". From them, in their own turn, will flow all manner of good things that we can call progress. If, right now, these facts seem to be completely impractical and useless, why, let us all have faith.

All very nice and simple. A box here, and a pigeonhole there. Neat. The only problem is, which is which? Also, how do you apply it to cases?

There was a time when it was simple. A time when scientists puttered around in cluttered laboratories, emerging only occasionally to publish papers of interest mainly to other scientists. A time when engineers were a mixture of mechanic and backwoods inventor only one step removed from the forge or steam engine.

Unfortunately, life has become more complicated. Engineering and science have become massively intermingled in interlocking projects of enormous scope — radar, missiles, nuclear fusion, etc. The scientist has become involved with devices of astonishing complexity, and the engineer with concepts of increasing subtlety. Although the distinction remains ultimately valid, it has long ceased to be at all simple in its application.

It is a reflection of this change that so many programs are simply labelled "R & D," thus ducking the issue entirely.

A difference, to be a difference, must make a difference. But this problem does make a difference. It is fundamental to everyone who is in either a deciding or judging role, and hence also to those whose activities are thus decided or judged. If the object of the program is knowledge, then that is one thing. If it is a device, that is another. The choice of program, the choice of people, and their final evaluation as successful or not, all hinge on the nature of the program and whether it is a scientific or an engineering one.

It is of no help that both kinds of programs may exist in a single organization. That a business, for example, that hopes to make profits from the devices that it makes, may still find it worthwhile to undertake pure scientific research. It does so, of course, on the principle that almost any knowledge will someday be useful. It is prepared and able to wait with more or less patience for that knowledge, in its good time, to breed devices. It has found that it is ultimately profitable for some fraction of its programs to yield immediately only a better understanding of nature.

One cannot tell the nature of a program by the purpos of the organization that supports it. Neither is it sufficien to know the "high level" objective. Both types of program can get completely mixed up with each other, and eithe can be subordinate to the other. A program to studi cosmic noise and its implications regarding the natur of the universe may first require the engineering of radio telescope. To build this telescope may require low noise amplifier that can be built only after th elucidation of certain solid state phenomena. The tw types of programs interlock in such a way that it i wholly inadequate to know the nature of the ultimat purpose.

The difference exists. It is necessary for the health o the institution, the program, and the people involved tha this difference be recognized and the activity properl categorized. But it is often astonishingly difficult to spli the whole up into parts that can be categorized accuratel and unambiguously.

The problem arises from the fact that many engineerin programs, particularly those of an "advanced" nature, re quire the engineer to discover and explore new basic con cepts. He finds himself looking quite actively and con sciously for "facts of nature." Only by finding such, unles he is incredibly lucky, can he accomplish his objective Only after the significant laws have been discovered, an their implications seen, can he see through to the devic that is his goal. In many cases, in fact, it is only then tha he can fully define the gadget that is his goal.

It also arises from the fact that science keeps gettin ever more subtle. This, in turn means that, in seeking th answers to many of their questions, scientists find them selves building exceedingly complex instruments. Witnes the linear accelerators, the radio telescopes, the instru mented satellites. The complexity of these gadgets i such that they require exceedingly painstaking desig If in most cases the more elaborate gadgets are bui as subordinate projects that are frankly engineering, th scientist must still lay down the specifications. He mus still understand the nature and the limitations of the too he is finally given. He can ignore the device itself onl at the risk of remaining ignorant.

To the outsider looking in, the distinction between th scientist and the engineer is not to be seen in what actually happening at any given moment. Over the sho term, the two types of programs may be utterly indis tinguishable.

Which, as aforementioned, is not to say that there no difference. Nor that the difference is trivial, either t the person doing the work, or to the executive who paying the freight or is otherwise concerned with seein the job done properly.

On the contrary, the difference is profound. It is, i essence, a difference in attitude. It is a question of pu

pose and of the personal goals involved. This attitude, in the end, determines the program; not necessarily as written down and prettied up, but the program as actually executed. It determines the directions that are taken, the priorities given the different aspects, and, finally, the accomplishment actually obtained.

That the decisions that create this difference may often be sub-conscious, being simply the general reaction to the situation as perceived, only makes the difference more vital. The difference is, in fact and in effect, a profound one.

The engineer, we say, is device-minded. This is not quite correct. He is not concerned with it either as a particular chunk of hardware as is the shipping department, nor even as a generalized chunk of matter, as is the salesman. He is, instead, concerned with it as an abstraction defined by its function and significant attributes. This includes such attributes as its potential cost of manufacture, if this is pertinent. Therefore the engineer is concerned, not only with building a thing with certain electrical and mechanical capabilities, but also with building it in the "best" way — the term "best" to include whatever factors are important for the whole function involved. He is concerned with possible techniques, and with the optimization of method versus the whole situation.

The scientist, on the other hand, is concerned with the device only as a tool with which to work. He is concerned that it shall do the job as he defines it, and not that it shall do it in any "best" way. He is satisfied if the technique is adequate, and does not bother if it be "best."

Both of these viewpoints are, of course, idealized. The engineer is forced to compromise by the fact that he lacks some of the essential scientific knowledge. Often he is operating on the front line of engineering knowledge, and considerably in advance of science. Always there is some degree of ignorance involved. To the extent that this ignorance exists, so must he study nature to determine what approaches he must consider in asking which is "best."

He must also compromise because of the enormous scope of any true definition of "best." Consider, for example, the typical problem of determining the appropriate time to transfer a product from development to production.

As every executive knows, the development engineer, if left to himself, would keep all products in development until the plant rusted away. Actually, in an industrial concern, the "best" time is that at which the company will, in the long run, make the most profits. The engineer, however, is usually neither trained nor sufficiently informed — and probably does not have either the interest nor the time — to evaluate the problem on those terms. He must think instead in terms of technical performance, reproducibility, cost of manufacture, etc. He accepts or quarrels with, but cannot truly argue, company policy and decision regarding marketability, factory loading and continuity of operation, capital availability, and other managerial aspects. He has strong but sometimes unbalanced opinions of such intangibles as pride of company and individual reputation which also ultimately affect profits. All of these factors, and others, come to a focus in the single problem of determining the "best" time of transfer. But the engineer cannot conceivably evaluate all of these factors properly. He is forced to represent, and fight for, his own area of competent judgment.

If we admit that the engineer, studying this problem of the timing of transfer from his own viewpoint among the trees, may tend to overlook the forest, perhaps we can also suggest that the executive may sometimes miss the trees. That, if the engineer tends to be impressed by the problems that he sees in an early transfer, the executive may not appreciate how real these problems are.

The real difficulty of this problem — and of many others that involve the engineer, too, is that a complete analysis, including all the many factors and their devious interactions, would be exceedingly difficult, and usually impossible. If it could be done at all, it would certainly take far too long, even with a whole battery of computers. Before a definitive answer could possibly be obtained, the factory would, indeed, have rusted away.

The engineer is therefore forced to use the term "best" as an operator that is only partially defined and can only be used approximately. For much of its content, he must use experience — which probably is the distorted memory of what he, or somebody else, did or did not get away with in a previous situation that was not really comparable. The justification of this obviously inappropriate process is that there is no better alternative.

The engineer, therefore, sits between the worlds of the scientist and of the "practical" executive. The compromises that he is forced to make are results of the fact that neither of these contingent areas gives him firm and useable boundary conditions. The resultant compromise is a profound one.

The scientist, too, must compromise. He dare not, in fact, ignore the device. In the first place, the accuracy with which he can control or determine the boundary conditions of his experiment are limited by the design and accuracy of his devices. Secondly, the subtlety of modern scientific investigation has, in many areas, reached the point where the design of the device is a key factor in determining whether a significant measurement can be made at all.

There are other factors, too. There is the question of repeatability. It is a rule of science that an observation should be repeatable by any other qualified experimenter. It is not required that this be easy to do. The fact that it may not ever actually be repeated has nothing to do with anything. It is enough that there be confidence that it *could* be repeated. In fact the likelihood that it will be repeated is inversely related to the level of confidence that it could be, and this level is partly determined by the extent to which good design enters the device. Which leads us to the odd conclusion that, ideally, the device should be so well designed, and hence so simple to build, that no one will bother to build it ever again.

There is also the matter of flexibility. Nobody wants to spend years and kilo-dollars, or to underwrite spending such, to build a device for just one measurement. It is obviously worthwhile to put at least some effort into so designing the device that, after it has done the job at hand, it can be adapted to for other uses. Since these future uses are probably not known at the time, this means that the device should be adaptable in as many directions as possible, and this requires very careful design.

So even in a scientific device, there is still an operative definition of "best" design and technique. Such programs still have their engineering aspects, no matter how purely scientific their objectives. How important these aspects may be will vary from program to program, but they are

The 6116/TE-39 ruggedized Reflex Klystron thermally tunes a band of 8500 to 9660 MC by means of a diode within the vacuum envelope. Tuning speed over the required frequency range is 0.7 seconds min. to 3.0 seconds max.

The 6940/TE-58 is identical to the 6116, but has special characteristics limiting spectrum width and spectrum continuity under adverse load conditions.

The 6845/TE-59 is similar in electrical and mechanical characteristics to the 6116 but may be operated under pulsed conditions with minimum frequency modulation.

BENDIX RUGGEDIZED REFLEX KLYSTRONS WITH THERMAL TUNING

The 6116/TE-39 Klystron tube combines ruggedized construction and *thermal tuning*. The combination provides a desirable tube for use in airborne radar and similar applications. Ruggedization makes possible a frequency jitter of less than ± 1.3 MC . . . at vibration levels up to 10 G at 50 cps. Thermal tuning provides a twofold advantage. It permits tuning the tube over its entire operating frequency remotely without mechanical means—and the tube can be repeatedly cycled throughout its tuning range without damage or deterioration.

These Reflex Klystrons are but one example of how Bendix Red Bank technology can help you meet specialized tube needs. For information on these tubes . . . and on backward-wave oscillators and traveling-wave tubes . . . write RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

West Coast Sales & Service: 117 E. Providencia Ave., Burbank, Calif.
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CIRCLE READER SERVICE CARD 4

always there. In the extreme cases, they lead to the establishment of sub-projects that are purely and frankly engineering. But even in the less elaborate programs, the scientist must in fact compromise his theoretical disdain of the device.

We conclude, then, that the problem of distinguishing between engineering and science is both important and complex. It is important because, in various overt and subconscious ways, it may have a determining effect on the results of the program. If the individuals involved are mismatched to the objectives accepted by those who must decide and judge, or if the individuals concerned do not fundamentally agree on what are those objectives, then the consequences to the program and to the individuals can be serious. It is an unfortunate fact that there is no simple test to determine in which pigeonhole a given project really belongs, or whether the apparent understanding is a true one.

The usual answer of lumping all together in the catchall "R. & D." is no solution. It solves the problem by ignoring it. This would be all right if the problem were only a semantic one, but it is not.

The problem is real, it is present. It makes a real difference. And if there is no pat answer, this merely shows the necessity of real understanding. Real understanding of their own motives and objectives by the people doing the work, be it engineering or science. And real understanding of other people by those who initiate, approve, and, in the end, evaluate. There is no substitute for understanding.

We wish to emphasize again that "the journal" is interested in receiving papers from the industry.

Papers can be addressed to: "the microwave journal," 159 Linden Street, Wellesley 81, Mass.

In the West Coast area, please address all papers to: "the microwave journal," Box 1134 Palo Alto, California.

Papers submitted for publication should include: 1. Two legible copies. 2. An abstract. 3. ORIGINALS of all the figures, with caption where needed. Photographs used as figures should be glossy prints. 4. A biographical sketch of the author. 5. A glossy photograph of the author, at minimum, 4″ x 5″, preferably, 5″ x 7″ or 8″ x 10″.

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON MANUFACTURING COMPANY, WALTHAM 54, MASS., Vol. 1, No. 3

NEW AMPLITRON* BOOSTS L-BAND RADAR OUTPUTS TO MORE THAN 5,000 KW

Extends range to radius of 250 miles at 80,000 feet

Now being incorporated in L-band ARSR systems for the C.A.A., Raytheon's new broad-band QK-653 pulsed-type Amplitron transmits ten times more power than maximum power levels of original RF drivers, increasing the detection range of these systems more than 60%.

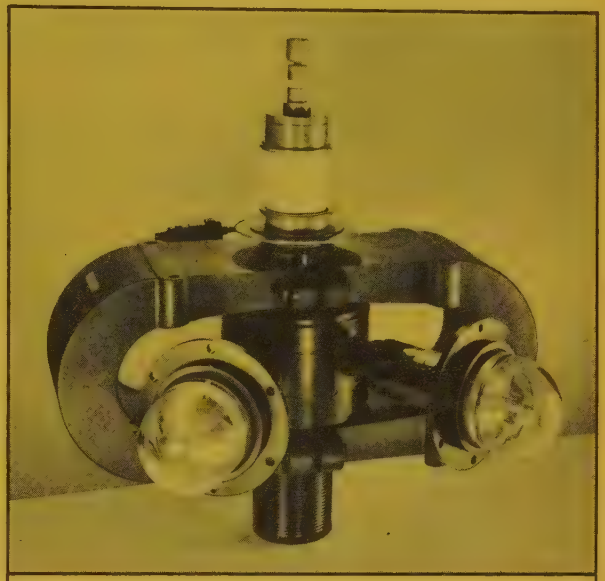
The Amplitron is a highly efficient (50% to 70%) liquid-cooled, integral-magnet microwave tube.

When used with Raytheon's new high-gain 40-ft. antenna, the QK-653 triples the detection range and the warning time of standard long-range search radars.

Non-reentrant RF circuit permits control of oscillation by frequency of RF input over the entire band, 1,280 to 1,350 Mc, at optimum gain and efficiency, without mechanical or electrical tuning. Changes in anode current or voltage have little effect on total phase shift. The Amplitron exhibits excellent reproduction of input spectrum even under high-ripple pulse conditions.

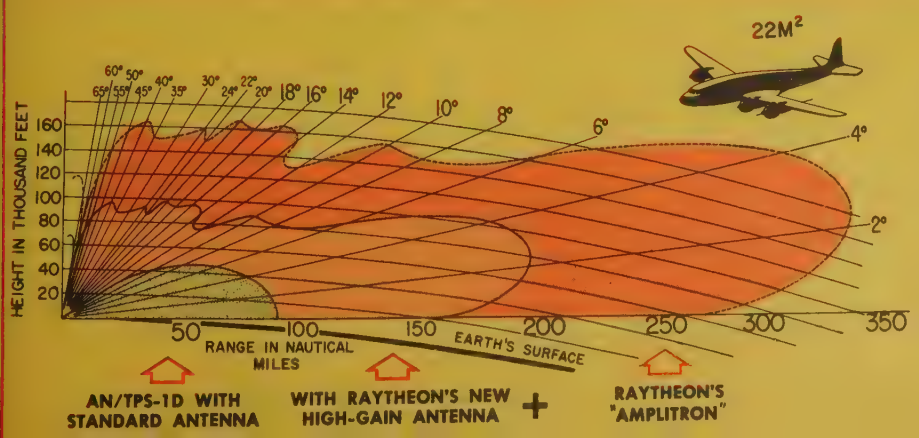
The exceptional phase stability of the QK-653 is particularly advantageous in MTI radar applications.

* Raytheon Trade Mark

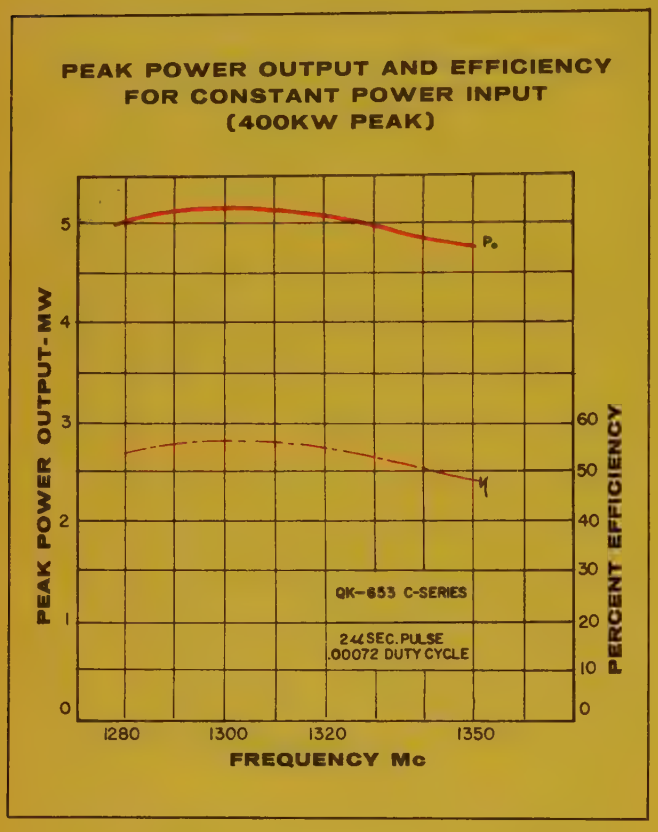


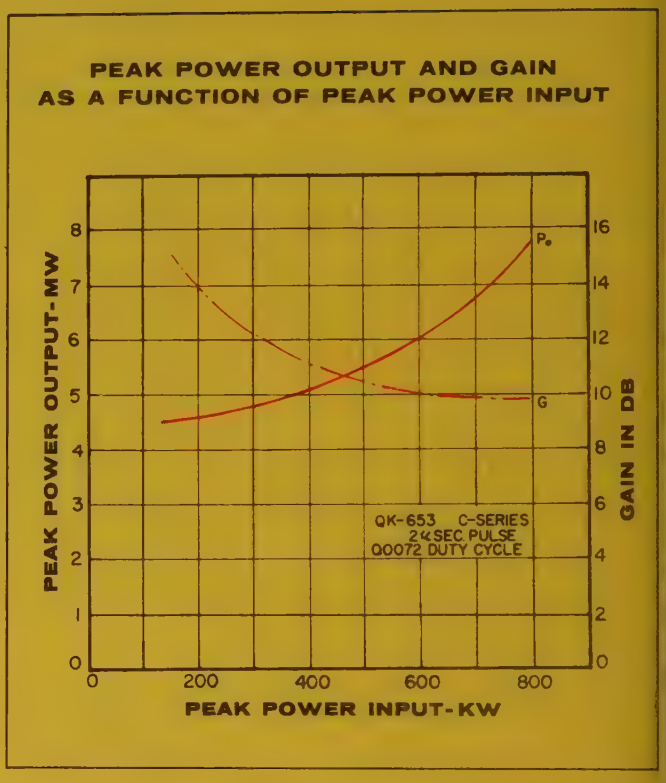
Typical Operating Characteristics

Anode Voltage	94 KV
Anode Current	78 amps
Peak Power Output	4 MW
Average Power Output	2,880 W
Efficiency	55%
Gain	10 db
Operating Band	1,280–1,350 Mc
Peak Power Input	400 KW

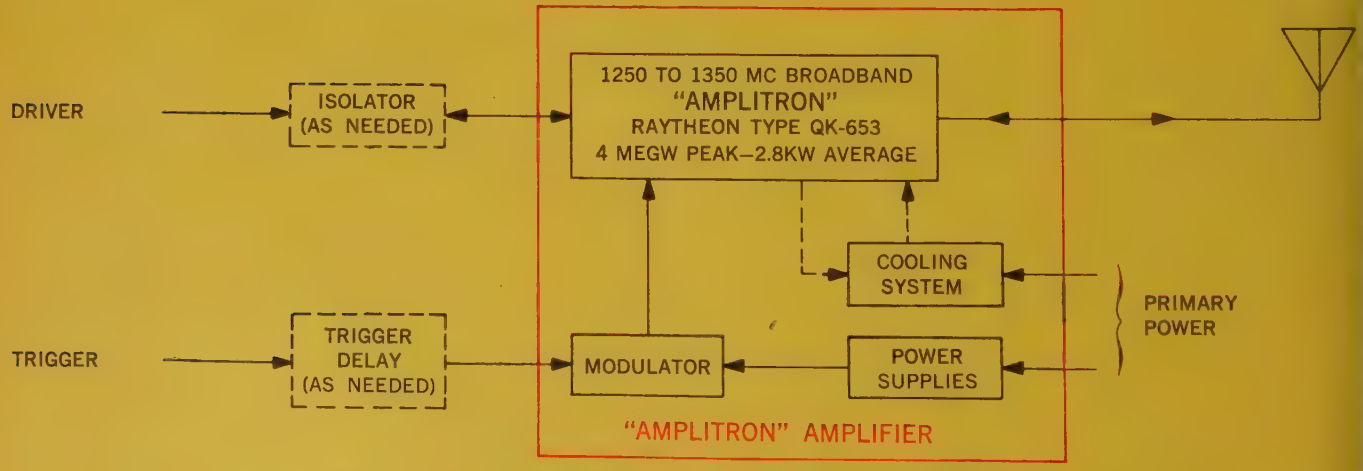


300% increase in coverage and warning time of type AN/TPS-1D radar results when Raytheon's new QK-653 Amplitron and 40-ft. high-gain antenna are added to the system. With other radars of more limited range, improvement factor may be even greater.





Block Diagram of Typical Amplitron Installation



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Letters to the Editor

Editor
he microwave journal

Dear Sir:

The central theme in the discussion f "total effective system noise" con-ributions in the article: *A Thermody-amic Analysis of Maser Systems** is: he "total effective system noise con-ribution of a noise source in a par-icular system is equal to the effective oise contribution of the source in he absence of all other sources of oise, multiplied by the product of ll losses forward of the point in the ystem at which the particular noise ontribution is introduced."

The contribution to the total sys-em noise produced by antenna "back obes" viewing the earth as a thermal eservoir should then be multiplied by ll losses forward of the point in the ystem where this noise contribution s "inserted" i.e. all losses from the ntenna forward.

In the expression for "total effective ystem noise" the antenna "back lobe" ontribution should therefore appear n the form:

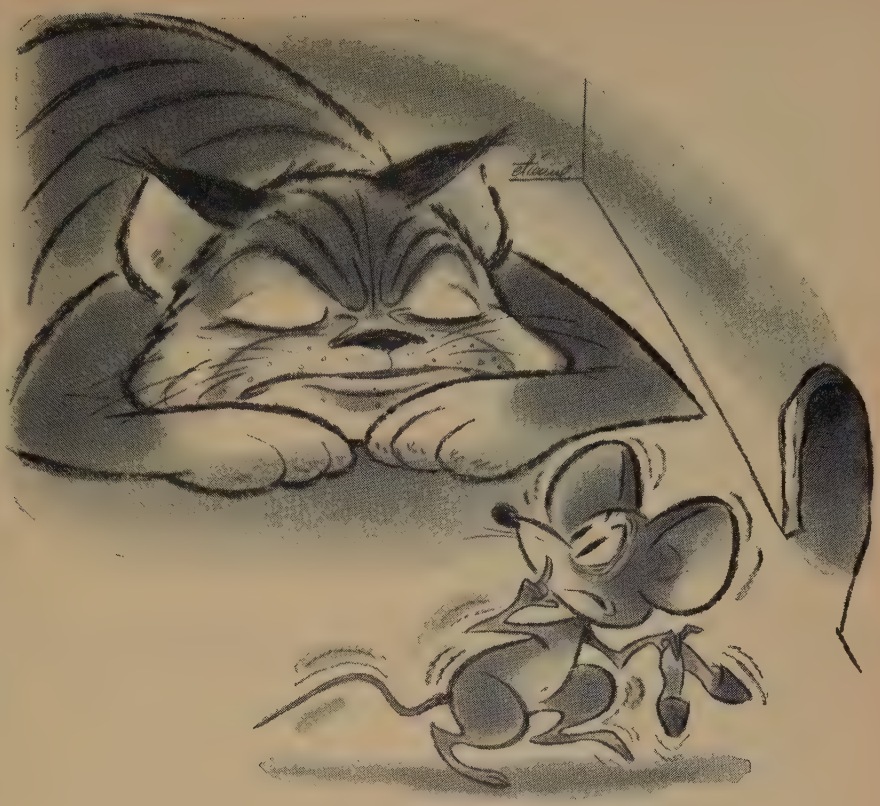
$$T_{BL}\ L_{O_2}\ L_{H_2O}\ L_I$$

T_{BL}, in the text, should be replaced by the above expression, or should be redefined as "the total *effective* noise ontribution of back lobes." Forward obes of the antenna, of course, are reated in a similar manner, however he complete expression will involve he relative intensity of re-radiated tmospheric temperatures, cosmic oise and discrete sources contained n the appropriate integration over pace coordinates as determined by the irective properties of the antenna.

From the basic concept one can ex-and on each term for a particular ystem as described in the original ext, taking into account space and ime coordinates. The final form of he equation for "total effective system oise" will depend, in each case, on he particular system and a careful efinition of terms. The definition of ach term should be related to the ethod of measurement.

The fundamental concept can be resented in a variety of ways with he inescapable conclusion, however, hat low internal noise r.f. amplifiers

(*Continued on page 14*)



When low noise level is vital...

Microwave Associates – developers of the famous low noise "E" series silicon diodes – now brings you

COAXIAL DIODES

with noise figure improvement of:

1.5 db at 16 KMC with the **1N-78B**
3 db at 25 KMC with the **1N-25A**
3 db at 35 KMC with the **1N-53B**

Simple substitution of these new coaxial diodes for existing types should improve your overall receiver noise figures as shown. No holder or IF amplifier redesign is required to realize system improvements with these improved versions of the standard coaxial mixer diodes.

Microwave Associates is now delivering these diodes as well as the new tripolar types. Typical of these breadboard types is the 1N630 which covers the frequency range of 1 KMC to 12.4 KMC.

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CIRCLE READER SERVICE CARD 5

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Send for details on what has been described as the most advan engineering staff in this field—and literature on our standard li and design facilities. Address: Frequency Standards, Box 504 Asbury Park, N. J. PRospect 4-0500. Or your nearest represen tive in all principal cities.

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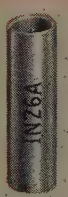
1N1838

The first and only Germanium Mixer Diode specifically designed for ultra-low noise performance in Doppler receivers. A noise temperature ratio specification of 24db max at 20kc guarantees this performance. Through Philco's exclusive anchor whisker construction the practical elimination of microphonics is assured. The 1N1838 is hermetically sealed and has been uniquely engineered for Doppler equipments operating at 8,800 and 13,500mc.

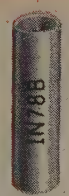
1N263

Here's a Hermetically Sealed Germanium Crystal Diode designed for exceptionally low noise mixer performance at X-band. It has been engineered to such a degree that its tightly controlled characteristics assure that *any* two 1N263's will be a matched pair; its symmetrical construction allows easy polarity reversal in balanced mixers. The crystal may be used fixed-tuned over the range 8600 to 9600mc. IF impedance (Z_{if}) . . . 140 to 210 ohms; RF impedance (VSWR) . . . 1.3 max; Overall noise figure (NF_{rec}) . . . 7.5db max.



1N26
1N26A
1N26B

These Silicon Mixer Diodes bring tremendously improved performance to this family designed for high reliability operation in the 24,000mc region. As a result of Philco's unparalleled engineering activity in this area, existing performance limits in the 1N26 series have been greatly extended: by addition of the 1N26B . . . maximum operating temperature more than doubled (to 150° C.); VSWR reduced to 1.5; IF impedance range narrowed (400 to 600 ohms). All members of this family have a metal-to-ceramic hermetic seal guaranteeing reliable performance under extreme environmental conditions.



1N78
1N78A
1N78B
1N78C

These Silicon Mixer Diodes offer new and unsurpassed performance characteristics to this established family designed for maximum sensitivity operation in the 16,000mc region. The new member of this family is unilaterally interchangeable with existing types while incorporating strikingly superior features: conversion loss (L_c) reduced to 6.0db max; IF impedance (Z_{if}) range tightened (400 to 550 ohms); RF impedance (VSWR) reduced to 1.5; temperature range extended (150° C.). Engineered to meet the most demanding military applications, all the members of this series are packaged in a hermetically sealed case.

Write* Special Components Dept., MJ 359 *Lansdale Tube Company Division, Philco Corporation, Lansdale, Pa.

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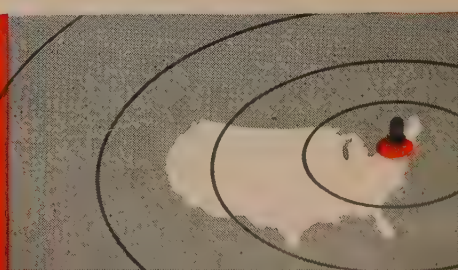


FROM THE EDITOR

Recently we wrote about the problem of standardization of frequency designations. At the time we indicated that although it was a problem it was not too serious.

There is another area of possible standardization, however, that deserves more concentrated attention. That is in the field of symbols for microwave components. The need for standards has been brought to our attention several times in the past. A recent letter from Clarence Radius, head of the Electronic Engineering Department at California State Polytechnic College suggested that "the journal publish a chart of accepted symbols and adopt an editorial policy of using these symbols wherever appropriate in articles."

The problem of devising a comprehensive set of symbols for microwave components appears to be quite difficult. With new components being added all the time and complete concepts being periodically revised it would seem an insurmountable task.

We have seen a few recommended sets of symbols but none of them to our knowledge has received universal acceptance.

The ones we have seen are usually a modification of existing symbols used in conventional lumped constant circuit diagrams. There is no serious objection to this approach except that it might be wiser to consider what the problem is in terms of the components under consideration.

At microwave frequencies the components are very often of the distributed parameter types and; consequently, it might be worth considering a whole new concept of symbol designation. For example, resistance, inductance and capacitance are parameters commonly used at microwave frequencies. In a typical microwave circuit, however, it would be unwieldy to draw a diagram in terms of these parameters. Under these conditions a variable attenuator, for example, would have to be drawn as a combination of at least 3 ganged variable resistors.

It is true that this type of designation would be accurate. As microwave systems become more and more complicated, however, it appears that in the interests of simplicity it would be wise to reduce components of this general type to a symbol that is both readily recognized yet easy for the engineer to draw.

We are suggesting the possibility of a whole new concept of symbol designations keeping in mind the basic requirements of a good microwave circuit diagram. The most accepted method in vogue at the present time is the block diagram technique which is probably adequate but certainly shows no imagination.

If anyone has knowledge of a good set of symbols, we would be most pleased to hear from them.

The May issue will include papers by Greene and Lombardo of Airborne Instruments Lab. on Low Noise 400 mc Reactance Amplifiers; M. C. Waltz of Bell Labs on A Technique for the Measurement of the Microwave Impedance in the Junction Region of a Semi-Conductor Device and D. F. Meronek and J. Van Bladel of The University of Wisconsin write on Resonant Modes and Frequencies of a Cigar-Shaped Cavity.

Paul Garrison, Sales Manager of the Special Products Division, of ITE will contribute a Business Editorial.

Theodore S. Saad

Letters to the Editor

(*Continued from page 11*)

have redirected our attention to pr viously "negligible" sources of sy tem noise, which are now major co tributors in determining system pe formance, and will require caref thermodynamic analysis in each case

I would like to thank "Gus" Eb Commander, USN, for pointing o the lack of consistency in treati the term T_{BL} in the original paper.

Sincerely,
"DOC" EWEN
Ewen Knight Corporati

*March issue, *the microwave journal.*

• ● •

To the Editor of
the microwave journal:

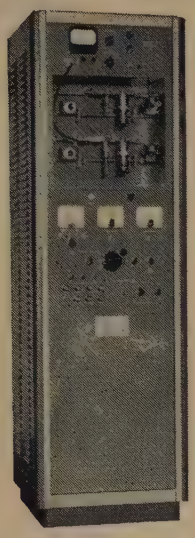
We read with interest the article Professor Süsskind about the teac ing of microwaves in colleges. T article, however, was perplexing several aspects. It was difficult ascertain where Professor Süsskir was referring to graduate instructi or undergraduate instruction or po sibly both. We are somewhat su prised at the textbook criteria b cause we have had difficulty in fin ing suitable texts for both our gra uate and undergraduate microwa courses. Professor Süsskind lis three core books. One, Ramo ar Whinnery is an excellent interm diate fields and waves book that d votes but a single chapter to micr wave networks. The second, Bro well and Beam, is mainly an exce lent introductory text to fields ar waves. The beginning of the boo contains a good (for 1947) trea ment of microwave tubes. There also, some descriptive material systems and some transmission li analysis. The third book, Reich et a is apparently designed for a micr wave course. Both of us have tri to use the book and its sequel for t New York University undergradua course and have found it unsuitab for a modern microwave circui orientated course.

Professor Süsskind also lists tw books as advanced texts. Both these, it is true, have material whi is useful for graduate courses b both have well known limitation There is, also, a recent text on micr wave measurement which we are no using for our undergraduate micr

(*Continued on page 16*)

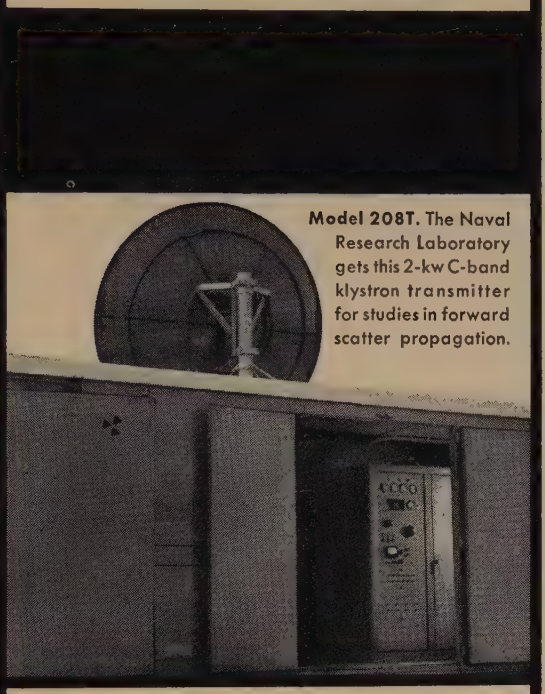
WORK IN PROGRESS AT LEVINTHAL

Among the various projects on the work docket in the Levinthal Stanford Industrial Park plant, these samples give a hint of the breadth of capabilities existing here.



Model 99P. An 18- to 40-kmc 1-mw signal source for Douglas Aircraft Company. Designed for counter measures, this instrument also serves as a general-purpose laboratory device.

Model 240T. A 17-mc transmitter for propagation research, this unit provides 400 kw of peak power. User is the University of Alaska.



Model 208T. The Naval Research Laboratory gets this 2-kw C-band klystron transmitter for studies in forward scatter propagation.

Pulse-Current Transformers. One of the more standardized product lines in the Levinthal Pulse-Transformer Department, these units are designed for monitoring cathode currents of klystrons, magnetrons, amplitrons, or twt's.

1Q1, 75-kv, 150-amp pulse, $275.
1Q2, 150-kv, 150-amp pulse, $348.
1Q3, 250-kv, 200-amp pulse, $402.

Model 224M. This is a 20-kw 200-mc pulse power amplifier for Brookhaven National Laboratory. It will serve as part of an r-f driver chain for a linear accelerator.

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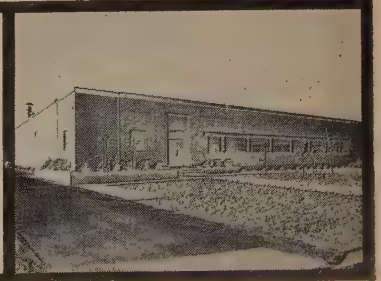
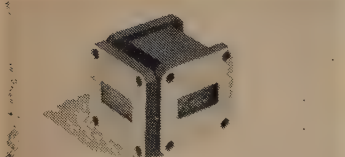
Major products of the Levinthal Equipment Division are transmitters, modulators, high-power pulse transformers, power supplies, and related accessories for application to radar, missile guidance, communications, and tube development. Ask us for details or bring us your special problems.

If you think you would find designing equipment of this general type fascinating, maybe you should consider the possibility of coming to work at Levinthal. Get a resume shipped off to us today.



Microwave Component News from SYLVANIA

NEW Space Saving Ferrite Devices



Three-port Circulator, Model FD-TC 522

Coaxial Ferrite Isolator, Model FD-155

Sylvania introduces new ferrite devices covering UHF through K band

Sylvania scientists and engineers have developed advanced ferrite devices with new utility and reliability. They are the results of pure research and product development by the Microwave Physics Laboratory, now a part of Special Tube Operations.

Now, new Tee circulators are available that perform the same electrical function as standard phase shift circulators, yet occupy only 25% of the space and cost much less. The devices can also be used as isolators and as fast-acting switches.

New isolators, available in coaxial and standard design, incorporate exclusive space-saving features in addition to outstanding electrical performance. The 8½-inch FD-151, for example, provides 15-db isolation across the band from 2-4 kmc. Whatever the degree of isolation required, you'll get a smaller package and top reliability from Sylvania.

Data on Sylvania ferrite devices available from stock may be obtained from your Sylvania representative or by writing to the address below. Devices can also be custom designed to meet your specific requirements.

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
Special Tube Operations
500 Evelyn Avenue, Mountain View, California

CIRCLE READER SERVICE CARD 9

Letters to the Editor

(*Continued from page 14*)

wave course. Dr. Weissfloch's book, which is suitable for a graduate microwave circuits course, remains, unfortunately, untranslated.

The above comments, of course, are made in the thought that a microwave networks course is distinct from a fields and waves or microwave electronics course. There is no shortage of good advanced fields and waves books. There are also several books which deal adequately with the theory of microwave tubes.

We also wonder if the worth of a microwave laboratory course can be measured by the money value of the equipment used. Many principles of microwaves can be easily shown using the usual war surplus items available, plus some good school shop construction. We admit, however, that use of the newer "packaged" sources and excellent commercial components has made our own microwave laboratory experiments more convenient to manage.

Due to some unknown circumstance we never received Professor Süsskind's questionnaire. We would like to indicate here the extent of the microwave course with its associated laboratory.[1] In addition, we offer a number of graduate[2] courses in microwave circuits, measurements and electronics as part of the microwave sequence.[2]

1. E.E. 81 Microwaves
   E.E. 81L Microwaves Laboratory
2. E.E. 103 Introduction to Microwave Networks
   E.E. 225-226 Microwave Networks I, II
   E.E. 235-236 Microwave Electronics
   E.E. 267-268 Microwave Networks III, IV
   E.E. 269 Microwave Measurements
   E.E. 275 Microwave Filter Theory

D. J. R. STOCK
L. J. KAPLAN
New York University
Electrical Engineering Dept.

•

Dr. Süsskind has replied as follows:

Undergraduate and graduate programs were both considered in evaluating the results of the survey. The textbooks enumerated were used as

criteria because they WERE being used by most colleges, although not a few educators would doubtless agree that none of the books is perfectly suited as a text for this specific subject.

I assume that the book on microwave measurements to which the letter refers is Ginzton's *Microwave Measurements,* published in McGraw-Hill's International Series in Pure and Applied Physics in 1957 (i.e., after the survey was concluded). This text is the first in a group of three books (all to be published in the same series) that may go a long way toward solving the textbook problem. The second, Jaynes's *Theory of Microwave Circuits,* is scheduled for publication in early 1960, and the third, Chodorow and Süsskind's *Fundamentals of Microwave Tubes,* soon thereafter.

Failure to receive a questionnaire must be, I fear, attributed to a breakdown of internal communications in the institutions concerned. All colleges with EE departments received one, and those that failed to respond received a reminder and a second questionnaire a few weeks later. No replies were received from 5 (out of 152): Case, Columbia, N.Y.U., U. of Pennsylvania, and Stevens. Unfortunately, this list includes several of the institutions that are prominent in microwave engineering.

Charles Süsskind
University of California

• ● •

Editor,
the microwave journal
160 Warren Street
Roxbury 19, Mass.

Dear Sir:

Just a short comment on what I assume is a typographical error in the January '59 issue of your journal.

P. 30, Figure 6 of Part I, "Using the Smith Diagram"—The sentence which now reads:

"If the line is of infinite length it may spiral to some point P_3."

should read:

". . . of *finite* length . . ."

Sincerely,
H. B. QUERIDO
Research Engineer
Radar & ECM
Electronic Development Group
North American Aviation, Inc.

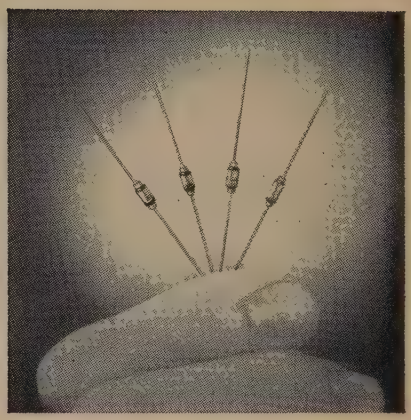
Many thanks to Mr. Querido for pointing out this error and our apologies to Dr. Southworth in whose paper it appeared.

The Editors

Microwave Component News from SYLVANIA

NEW Subminiature Microwave Diodes

Sylvania opens the way to advanced miniaturization concepts in microwave and radar design with new smaller Silicon Microwave Diodes



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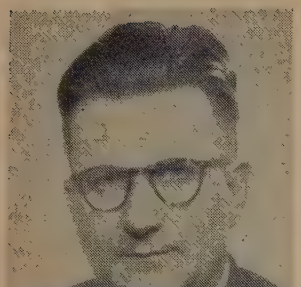
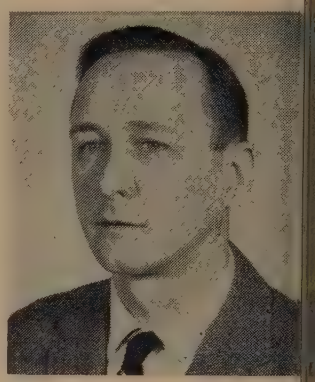


ROGER C. JONES was born in Lake Andes, South Dakota. He attended Omaha University and the University of Nebraska, receiving his B.S. in E.E. from the latter institution in 1949. His graduate work has been done at the University of Maryland, where he received the M.S. in E.E. in 1953. He is presently completing work on the Ph.D. (Major in E.E., minor in Physics) at the University of Maryland.

Mr. Jones was employed by the Naval Research Laboratory, Washington, D.C. from 1949 to 1957 where he worked on guidance systems for air-breathing missiles; atomic weapons instrumentation, participating in the first thermonuclear tests at Eniwetok Atoll; in the field of electron tube research, specializing in gaseous electronics; plasma propagation problems associated with the ICBM program.

Since 1957 Mr. Jones has been employed by Melpar, Inc., presently as Consulting Project Engineer. His work at Melpar has been largely in the fields of ECM, Antennas, Radar, and Propagation Theory.

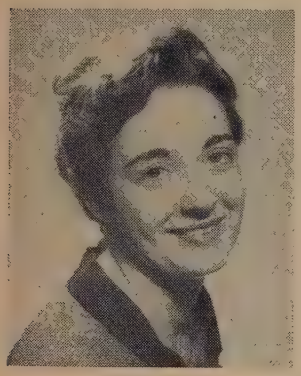
Mr. Jones is a senior member of the I.R.E. and a member of Pi Mu Epsilon and Eta Kappa Nu.



GIRARD RICE LOWREY, JR. received his A.B. in mathematics from Johns Hopkins University and his M.S. in physics from the University of Tennessee. He is now studying for the degree of Ph.D. in physics at Georgetown University.

He is a Senior Engineer at Melpar, Incorporated, Falls Church, Virginia and before that worked at E.R.D.L., Fort Belvoir, Virginia. His fields of specialization have included the negative hydrogen ion, certain topics in information theory, and antenna theory (especially the theory of antenna surface errors).

He is a member of Sigma Xi.

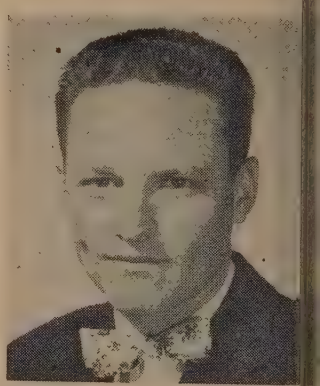


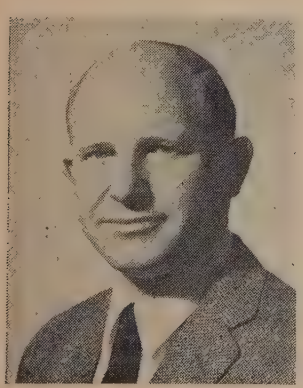
ELAINE LULOFF was born in Staten Island, New York in 1937. She received the degree of BEE from the University of Florida in 1958, and is now continuing her studies towards an MEE at the Polytechnic Institute of Brooklyn. After graduation she was employed by Polarad Electronics Corporation. Originally with the Publications Department, she helped with the organization and preparation of the curriculum for Polarad's Commercial Instrument School. She is presently with Polarad's Product Improvement Group where she is working on the design of a microwave signal generator.

ROBERT G. ROCKWELL was born in La Junta, Colorado, on August 20, 1922. He received a four-year scholarship to the University of Colorado, in Boulder, Colorado, and was awarded the B.S. degree in electrical engineering in February, 1944. At the University of Colorado he was also in the Naval ROTC, and following commissioning in February, 1944 spent the next two years in the South Pacific on an aircraft carrier, the USS Lexington. He worked the subsequent year with General Electric on the East Coast. Graduate work at Stanford University followed and in August 1949 Stanford awarded him the advanced degree of Engineer.

In 1949 he became a member of the technical staff at Hughes Aircraft Company in Culver City, California, primarily working in the Electron Tube Laboratory on low-noise traveling wave tubes. Since December, 1952 he has been a project manager with Varian Associates in Palo Alto, California.

His professional affiliations include Senior Member in the IRE, and membership in Sigma Xi, Tau Beta Pi, and Eta Kappa Nu. He is also a lieutenant in the Naval Reserve.





ROBERT SAUL received the degrees of BEE and MEE from CCNY in 1950 and 1952, respectively, after serving three years with the U.S. Army Signal Corps. He joined Polarad Electronics early in 1950, prior to receiving his degree. His early work in Polarad involved design and development of television monoscopes, monitors and synchronizing generators. In 1952 he became Chief Test Engineer, position he holds at present. In addition to his responsibility in this capacity, he has done considerable design work on microwave spectrum analyzers, receivers and signal generators and is presently in charge of the Polarad Product Improvement Section where both new instruments and improvements on existing commercial instruments are introduced and carried through. He has been collaborating very closely with the Polarad Sales Organization and has made major contributions in preparing educational technical literature.

Mr. Saul is a member of Tau Beta Pi and Eta Kappa Nu.

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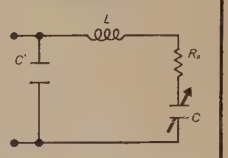
HPA 2800	0.1 μμf	2.5 μμf	70KMC	4 mμh @ 1KMC	5V	7V	
HPA 2810	0.2 μμf						

*At breakdown voltage **Breakdown voltage (10 μA point)

CAPACITANCE vs. BIAS VOLTAGE

Reverse Bias Voltage	Capacitance C
0 V	2.5 μμf
3 V	0.76 μμf
7 V	0.60 μμf

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Surveillance radars at major airports throughout the country will soon be equipped with completely new antenna systems for added safety in the control of jet age air traffic. This project will mark the second phase in the FAA's program to improve their performance and extend their range. I-T-E has participated in both phases.

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PLASMA RESONANCE SCANNERS

Roger C. Jones
and
Girard R. Lowrey, Jr.
Melpar, Inc., Falls Church, Va.

I. INTRODUCTION

Two fundamental properties of importance in gaseous scanners are plasma resonance and cyclotron resonance. In certain respects the phenomenon of cyclotron resonance is of more practical importance, but the requirement of a magnetic field, and the resultant anisotropic nature of the permittivity, complicates the discussion and impedes consideration of certain interesting cases. The discussion in this paper will be limited to analysis of devices employing plasma resonance, because the authors believe this case to reveal the possibilities (and deficiencies) of gaseous scanners in a simple fashion.

For purposes of this discussion, a plasma can be defined as a region of space wherein positive and negative charges exist in essentially equal numbers. Only rare gas discharges are considered here, and the constituents of the plasma will be assumed to be positive ions and free electrons, mixed, of course, with a very large number of neutral atoms in various states of excitation.

In the presence of a plasma, the effective permittivity becomes less than that of free space and is complex because of the electron-atom collisions. These characteristics of the permittivity lead to the phenomenon of an electromagnetic wave suffering attenuation but possessing a phase velocity in excess of that normally present, either in a bounded or unbounded medium. In the plasma resonance case the phase velocity is primarily a function of plasma density. By appropriate excitation methods the magnitude and nature of the electron density spatial distribution function can be controlled, so that it becomes possible to design phase shifters and lenses with their resultant scanning applications.

The main advantages of a plasma resonance type scanner are those of speed and versatility. That is, not only can the plasma density be modulated at a very high rate, but, also, the spatial distribution can be rather rapidly altered. There appear to be some short range — high speed applications requiring such capabilities.

In a large number of important cases, unfortunately, the disadvantages of a plasma resonance scanner (or even a cyclotron resonance scanner) become prohibitive. The attenuation is often excessive, the power handling capability is quite limited, and the generated noise, which is almost random, is of appreciable magnitude. The situation is somewhat the same as with ferrites, except gaseous scanners are practical to much lower frequencies and are more noisy. The losses of a plasma resonance type scanner, however, usually exceed those of well designed ferrite scanners at S-band and above.

Four cases are given theoretical consideration in this paper, and for one case, the linear array, a practical scanner is discussed and experimental data presented. The four cases are the following:

1. Wullenweber Arrays
2. Linear Arrays
3. The Quasi-Eaton Lens
4. The Quasi-Luneberg Lens

Consideration of the above plasma resonance scanners should provide adequate information for the design of other scanners employing phase shifters and lenses of the plasma resonance type. As with even conventional scanners, a certain amount of experimental work is necessary to produce a satisfactory device, but, fortunately, one usually finds that theoretical predictions are qualitatively correct. It is true, however, that any elaborate theoretical predictions require a reasonably sound knowledge of gaseous physics.

II. Propagation in Plasma-Filled Guides

For the applications considered in this paper, it is necessary to obtain expressions for the phase velocity and attenuation of electromagnetic waves propagating through plasma filled coaxial lines and rectangular guides. It is assumed here that the plasma is uniform and isotropic (no magnetic field).

The phase velocity and attenuation will be obtained in the normal fashion from a phase constant involving a complex permittivity. This permittivity contains the plasma conductivity term based upon a constant mean transport collision frequency. When employing these simplifying assumptions, the derivation for any desired transmission mode is relatively simple. However, the work here, which is easily extended, is limited to the TEM mode for the coaxial line and to the TE modes for the rectangular guide.

The constant average collision frequency expression for the conductivity of a plasma may be put in the form $\sigma = \varepsilon_0 \left(\frac{\omega_p}{\omega_\nu}\right)^2 (\nu - j\omega)$, where $\omega_p^2 = \frac{ne^2}{m\varepsilon_0}$, $\omega\nu^2 = \omega^2 + \nu^2$, and ν

is the average collision frequency. For TEM propagation one has that $\gamma^2 + K^2 = 0$, where $K^2 = \omega^2\mu_0\epsilon c$, and $\varepsilon_o = \varepsilon_c + \frac{\sigma}{j\omega}$. Solving for β (where $\gamma = \alpha + j\beta$), one finds that

$$Vp = \frac{\omega}{\beta} = \frac{\sqrt{2}\ C}{\sqrt{\left[1-\left(\frac{\omega_p}{\omega_v}\right)^2\right]+\sqrt{\left[1-\left(\frac{\omega_p}{\omega_v}\right)^2\right]^2+\left(\frac{\nu}{\omega}\right)^2\left(\frac{\omega_p}{\omega_v}\right)^4}}}$$

as the phase velocity for the TEM mode of propagation. Writing $\gamma^2 = p - jq$, one finds that $\alpha = \frac{q}{2\beta}$, or

$$\alpha = \frac{\left(\frac{v}{\sqrt{2c}}\right)\left(\frac{\omega_p}{\omega_v}\right)^2}{\sqrt{\left[1-\left(\frac{\omega_p}{\omega_v}\right)^2\right]+\sqrt{\left[1-\left(\frac{\omega_p}{\omega_v}\right)^2\right]^2+\left(\frac{\nu}{\omega}\right)^2\left(\frac{\omega_p}{\omega_v}\right)^4}}}$$

as the attenuation for the TEM mode. At quasi-plasma resonance the phase velocity becomes $Vp = \sqrt{\frac{2c^2\omega}{\nu}}$, and $\alpha = \sqrt{\frac{\nu\omega}{2c^2}}$.

One may derive expressions for Vp and α for rectangular guides by writing the usual equation $\nabla_{xy}^2 \bar{E} = -[\gamma^2 + (p-jq)]\bar{E}$, where $-K^2 = p-jq$. Applying the boundary conditions, one finds that

$$Vp = \frac{\sqrt{2c}}{\sqrt{\left[\left(1-\left(\frac{\omega_p}{\omega_v}\right)^2\right)-\left(\frac{\lambda o}{2a}\right)^2\right]+\sqrt{\left[\left(1-\left(\frac{\omega_p}{\omega_v}\right)^2\right)-\left(\frac{\lambda o}{2a}\right)^2\right]^2+\left(\frac{\nu}{\omega}\right)^2\left(\frac{\omega_p}{\omega_v}\right)^4}}}$$

and

$$\alpha = \frac{\left(\frac{v}{\sqrt{2C}}\right)\left(\frac{\omega_p}{\omega_v}\right)^2}{\sqrt{\left[\left(1-\left(\frac{\omega_p}{\omega_v}\right)^2\right)-\left(\frac{\lambda o}{2a}\right)^2\right]+\sqrt{\left[\left(1-\left(\frac{\omega_p}{\omega_v}\right)^2\right)-\left(\frac{\lambda o}{2a}\right)^2\right]^2+\left(\frac{\nu}{\omega}\right)^2\left(\frac{\omega_p}{\omega_v}\right)^4}}}$$

for the TE_{10} mode. The limiting expressions for bounded quasi-plasma resonance $\left[\left(1-\left(\frac{\omega_p}{\omega_v}\right)^2\right)=\left(\frac{\lambda o}{2a}\right)^2\right]$ are the same as for the quasi-plasma resonant limits of the TEM mode. The guide wavelength is found, of course, by the relation $\lambda g = \frac{Vp}{f}$.

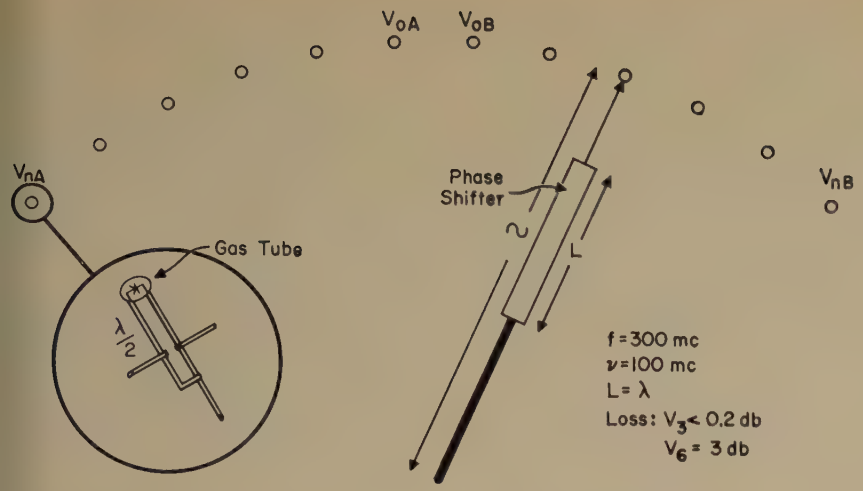
III. WULLENWEBER ARRAYS

The Wullenweber, or circular scanning array, is a desirable device for certain applications but the necessity for a mechanical commutator produces difficulties, including limited scanning speed. (A Wullenweber is a circular array of equidistant sources, usually vertical dipoles, ordinarily placed outside a cylindrical reflecting surface, for which the feed pattern can be rotated through 360 degrees.) There are applications of Wullenwebers in which the deleterious effects of gaseous elements can be tolerated and in which the objectionable mechanical motion of r.f. conductors must, if possible, be eliminated. Because of the phase advance characteristics of a plasma operating near plasma resonance and further, because of the existence of gas switch tubes, the usual commutator may be replaced by gaseous electronic devices; the secondary mechanical or electronic switching involved is not too objectionable.

Consider a parallel-fed Wullenweber with the delay lines replaced by plasma-filled coaxial lines and the rotational selection superseded by gaseous switching. The configuration is as shown in Figure 1.

One desires a plane wave front such that the total propagation time from a line normal to the optical axis must be identical for each element of the active portion of the array. For the zeroth element, one has $\tau = \frac{r(1-\cos\theta_o)}{c} + \frac{r}{Vp_o}$, and this must equal $\frac{r(1-\cos\theta_i)}{c} + \frac{r}{Vp_i}$, which is the propagation time for the i^{th} element. Hence, $Vp_i = \frac{Vp_o}{1-\frac{Vp_o}{c}(\cos\theta_o-\cos\theta_i)}$, as the necessary phase velocity for the i^{th} line given the natural phase velocity of the zeroth line. Clearly, the lines requiring the greatest phase velocity (largest plasma density) are also those requiring the most attenuation; fortunately the two situations go hand in hand, as is evident from an examination of the TEM equations.

Confining one's attention to VHF and low UHF Wullenwebers, the primary elements for a parallel-fed array are the coaxial delay lines running from the feed junction to the radiating elements, and a number of half-wave lines leading from the radiating elements to gas switch tubes. The two tubes on either side of the optical axis are weakly ionized, and their respective switch tubes are deionized. The extreme tubes of the array $Vp_{n_{a,b}}$ are ionized to the maximum extent, to provide the needed phase velocity — some of the attenuation which inevitably occurs is desirable. During the switching cycle Vp_{o_a} changes to Vp_{o_b}, Vp_{n_a} extinguishes and its switch tube fires; Vp_{n-1_a} becomes Vp_{n_a}, and Vp_{n+1} becomes Vp_{n_b}. Thus, the optical axis rotates one element per switching interval. Normally, there are only



36 Element Wullenweber Scanner (12 Elements Energized)

Figure 1 — Wullenweber Array.

active elements out of the N total elements; that is $n = \alpha N$, with a typical value for α being 1/3.

Consider an example where $N = 36$ and $n = 12$. Then $\theta_o = 5°$ and $\theta_n = 55°$, so that maximum phase velocity needed is $Vp_n = \frac{Vp_o}{1 - \frac{Vp_o}{c}(0.423)}$.

Choosing $Vp_o = 0.67c$, one has that $Vp_n \cong 0.93c$. If the gaseous section occupies a length εr, where r is the total delay line length, then $\tau_1 = \frac{r}{0.93c} = \frac{r(1-\varepsilon)}{0.67c} + \frac{\varepsilon r}{Vg}$ or $Vg = \frac{0.62\varepsilon c}{0.93\epsilon - 0.26}$; clearly $\varepsilon \geqslant 0.28$. Choosing $\varepsilon = 0.35$, then $Vg \cong 3.3c$; the limiting phase velocity is chosen as $Vp = c\sqrt{\frac{2\omega}{\nu}}$, so that for $\nu = 100$ Mc., and $\omega \cong 5.45 \times 10^8$ rad/sec., the maximum possible velocity becomes about 3.3 c. The attenuation anywhere in the region of plasma resonance is roughly $\alpha = \sqrt{\frac{\nu\omega}{2c^2}}$, which in this case would be about 0.54 neper/meter. Putting in the appropriate values, one obtains an attenuation of about 3 db, for the extreme elements of the active portion of the array.

The switch tubes are available commercially, although a special design would be more satisfactory. Obtaining a reasonable short circuit at these frequencies should be no problem.

IV. THE LINEAR ARRAY

We can now consider a waveguide slot array formed on a guide containing a gas tube. As the density of the plasma increases, the effective guide wavelength increases, as shown by one of the previous equations. The standard expression for the angle to the main beam from the array normal is $\theta = \sin^{-1}\left\{\frac{\lambda}{\lambda g} - \frac{\lambda}{2l}\right\}$ where l is the distance between slots. One may therefore scan, by varying plasma density, to an extent limited by the greatest practical increase in guide wavelength. The change in guide wavelength is small above so-called bounded quasi-plasma resonance, so the largest guide wavelength is taken to be $\lambda g = \sqrt{2\lambda^2 \frac{\omega}{\nu}}$. With proper slot design, therefore one could theoretically scan from $\theta = 0$ to $\theta = \sin^{-1}\left\{\sqrt{\frac{\nu}{2\omega}} - \frac{\lambda}{2l}\right\}$.

In practice, of course, a glass envelope encloses the plasma, and the plasma, which is of necessity non-uniform, cannot completely fill the guide.

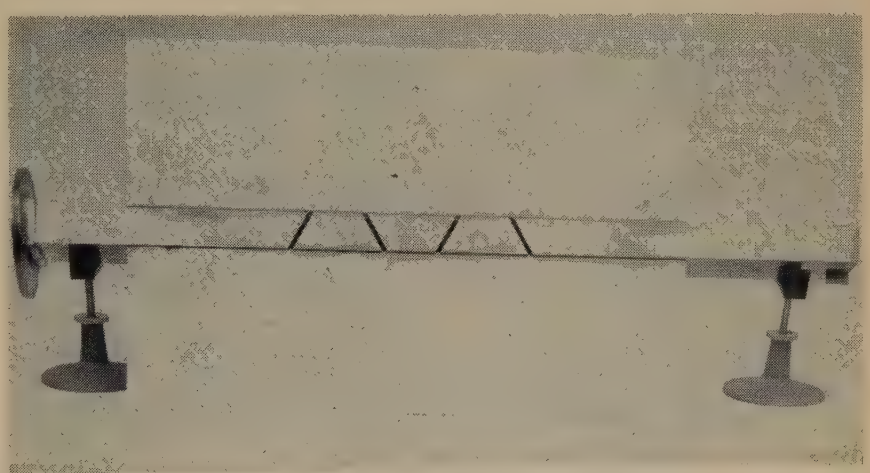


Figure 2a — Slot View of the Experimental Linear Array.

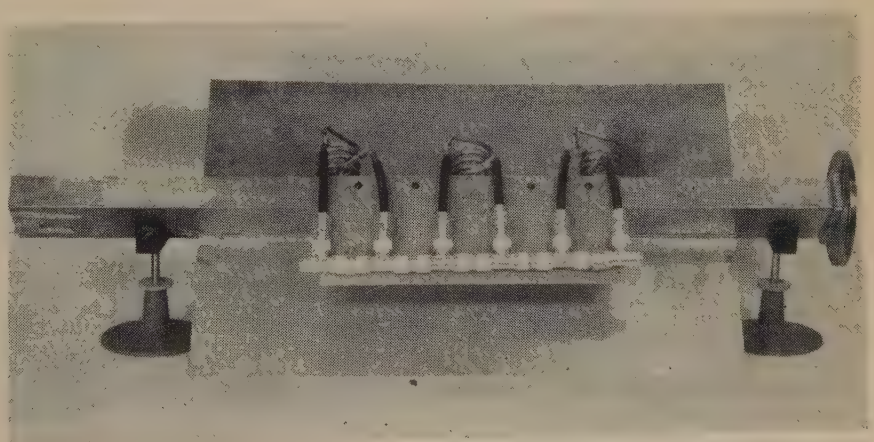


Figure 2b — Tube View of the Experimental Linear Array.

The first crude approach to prediction of scan angle would entail the use of an effective dielectric constant derived from the presence of glass, extent and density of the plasma, and the redistribution of the electric field. Because the dielectric constant of the plasma is less than unity, the electric field would be peaked in the vicinity of the discharge. The weighting of the plasma would, therefore, be much greater than its displacement and position would indicate at first glance. Of course, the logical, though difficult, approach is to solve the boundary value problem, from which one can, if desired, deduce an "effective dielectric constant."

If one designs the slot array for uniform illumination, the uniformity will disappear with the presence of a plasma. Feeding from one end, for example, the wave is attenuated at a maximum rate (uniform plasma filling the guide) of $\alpha = \sqrt{\frac{\nu\omega}{2c^2}}$ nepers/meter; thus, the far slots will receive much less power than desired. If one feeds from the center, then a desirable tapered illumination will occur, although a split beam will result without severe slot modification. Again, because of the limited extent of the plasma, the attenuation will not be so severe as indicated above.

An experimental gaseous linear array scanner was built as shown in Figure 2. As can be seen in a glance, this is no sophisticated scanner, but merely one designed to illustrate the principles involved. The slots were designed for uniform illumination, but not even the presence of the glass was taken into account. The large (1¾ inches in diameter) holes in the broad face of the guide (through which the excitation columns of the gas tube were placed) were also neglected. In addition, a greater pressure than was required was used in the discharge tube, to insure acquisition of proper plasma density, with a safety factor.

The discharge tube had an active column (the portion in the waveguide) of one inch in diameter, and the excitation columns were one and one-half inches in diameter. The tube was exhausted to about 5×10^{-7} mm Hg, and baked out quite thoroughly. After three flushings with spectroscopically pure Argon gas, the tube was filled with 1.5 mm Hg $\pm$ 10 per cent of Argon gas and sealed off. The active column rested on the bottom face of the guide, and the tube was held rigid with teflon inserts.

Following prior work by one of the authors along this line, the type of discharge selected was a combination "E" and "H" type r-f discharge at a frequency of 29.6 mc. The excitation columns were wrapped with four turns each of ¼ inch copper tubing. These coils were connected in series and fed with a coaxial line from the r.f. source.

The actual experiment was carried out as follows:

The gaseous linear array scanner was mounted on a rotating mast and fed with about 100 milliwatts of 2800 mc power. The detector was placed about 20 feet away in a fixed position. The signal generator was modulated with a 1000 c.p.s. square wave, the detector employed a narrow band 1000 c.p.s. amplifier. Patterns were taken with no power, 200 watts, 400 watts, and 600 watts of 29.6 mc power. Two hundred watts was sufficient power to produce bounded quasi-plasma resonance, so further increase in power did not produce an appreciable increase in scan angle.

The main results of interest is shown in Figure 3, from which it is seen that the shift is about 14 degrees. For lower gas pressure, a larger active column, and better slot design, this figure can be radically increased. The behavior would also improve with center feed, elimination of hole radiation, and the use of gas having a smaller characteristic average transport collision frequency, such as Neon.

For a completely filled guide, and using a transport collision frequency of 1.884×10^9 c.p.s., the maximum scan angle for the above system a 2800 mc should be about 26 degrees. It is believed that one could obtain bounded quasi-plasma resonance with a pressure of only about 0.2 to 0.3 mm Hg, so that the scan angle would go to about 33 degrees, for bounded quasi-plasma resonance and without other modification.

In conjunction with improved gas tube design, further work must be carried out on the problem of maintaining proper slot conductance during the scan cycle. A great deal of this work must necessarily be of an experimental nature.

V. THE QUASI-EATON LENS

One of the well-known variable index lenses is the Eaton type, which for the pure Eaton, produces a cylindrical wavefront. (An Eaton-type lens is a variable index lens which produces a conical wavefront from a point source on the periphery.*) The case considered here is that which produces a conical wavefront of variable cone angle, ranging from the pure Eaton ($\beta = 0$) almost to the Luneberg ($\beta = \frac{\pi}{2}$). The Luneberg case (the case of a plane wave-front produced from the point source on the periphery) cannot be approached too closely by the methods considered here or difficulties appear which necessitate a different sort of solution. This is explained in the section on the quasi-Luneberg type lens.

The pure Eaton lens has an index of refraction specified by $n = r$; this index variation is produced by a wave guiding structure which is compressed at the center and flared at the edges

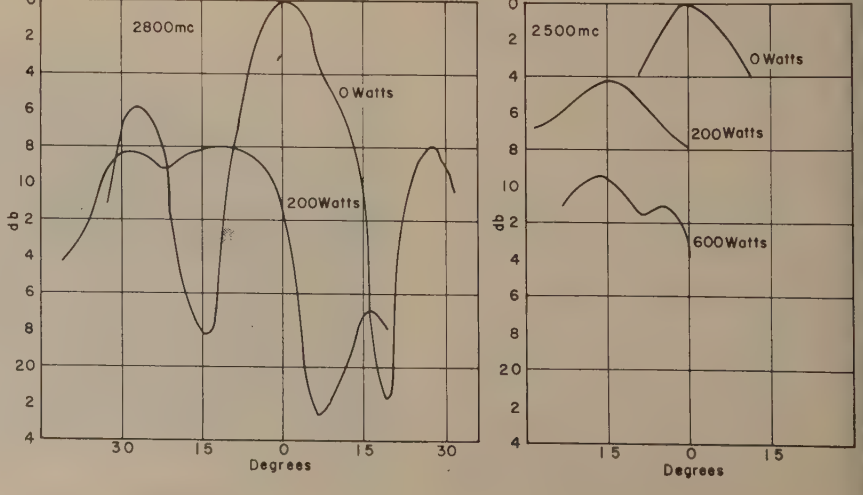


Figure 3 — Experimental Data for the Linear Array.

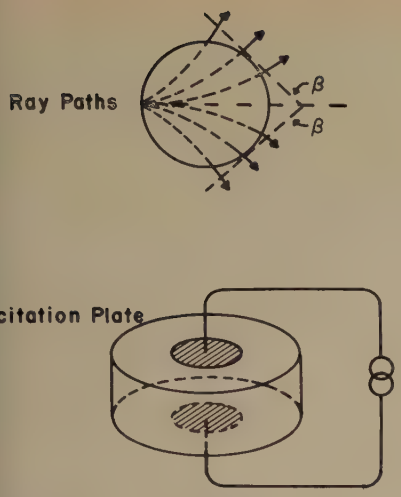


Figure 4 — Quasi-Eaton Lens.

The variation of such a structure would be extremely difficult, so the use is confined to that of producing a cylindrical wavefront, or at least a fixed cone angle. If one can generate a sufficiently dense plasma of the required spatial distribution however, then a lens producing a conical wavefront of variable cone angle may be constructed. (Cf. Fig. 4.)

In the plasma case the index would vary from a small value at the center to essentially unity at the dielectric boundary. Neglecting the thin glass boundary, one sees that the usual solution, $nr = \dfrac{2\left(\frac{r}{n}\right)^{\pi/2\beta}*}{1+\left(\frac{r}{n}\right)^{\pi/\beta}}$ applies. One cannot go to $n = 0$ with an actual plasma because of the electron atom collisions. One can go to a small value, however, and this is sufficient for most purposes. Figure 5 gives the plasma density distribution for a particular quasi-Eaton lens with $\beta = 30°$ (omitting a very small lip with n just above 1 near the edge, as well as the vanishing n at the center). As β increases the plasma density required will decrease, and the distribution function will change. It turns out that an "E" type discharge of sufficiently high frequency will cause approximately the correct type of spatial distribution function to appear, at least for values of β which are not too large.

*This result is due to K. S. Kelleher ("Variable Index Lenses Which Produce Conical Wavefronts," Electromagnetic Wave Symposium, University of Michigan, June, 1955).

VI. THE QUASI-LUNEBERG LENS

Luneberg lenses are quite satisfactory when constructed in any one of the several ways commonly used. (They are commonly constructed from variable density foam, expanded rubber, shells or slabs of dielectric, artificial dielectrics, or any method such that the dielectric constant varies in the correct manner from two at the center to unity at the edge.) The consideration of a less satisfactory type, such as presented here, may be of some theoretical interest, however.

If one examines the ordinary type of Luneberg lens, with the pertinent expression being $n^2 = 2 - r^2$, it is seen that the dielectric constant must be equal to 2 at the center and 1 at the edge. An ionized gas, however, has an effective dielectric constant which is less than unity, so one must have a tenuous plasma at the center ($n \cong 1$) and a more dense plasma ($n \cong \epsilon$, where ϵ is a small number obeying the Luneberg relation) near the edge. Now one must propagate into free space, where $n = 1$, so that severe, dispersive refraction would take place at the dense plasma-free space boundary (the glass is neglected). It is clear that this refractive process must be taken into account, and it is for this reason that the conventional Luneberg relation does not apply. One may approach the problem in several ways, but for the purpose of this paper the following approximate analysis is presented:

A Luneberg-like relation of the form $n = \sqrt{1 - ar^2}$ is employed, where $a = \dfrac{\sin^2\alpha_0 - \cos^2\alpha_0 + \cos\alpha_0}{2\sin^2\alpha_0}$ is a parameter selected to make initial rays at angle α_0 emerge parallel to the optical axis. Clearly $n(1) = \sqrt{1-a}$; and for $\alpha_0 = 30°$, for example, this becomes equal to 0.518. It is found that the 15° ray deviates only a small fraction of a degree; and this sort of analysis, crude though it may seem, is therefore very practical. The other approximation employed here (and in the Eaton lens) is that of the index of refraction in terms of the plasma parameters. It is assumed here that an index of refraction derived from the phase velocity in an unbounded plasma is a satisfactory approximation. That

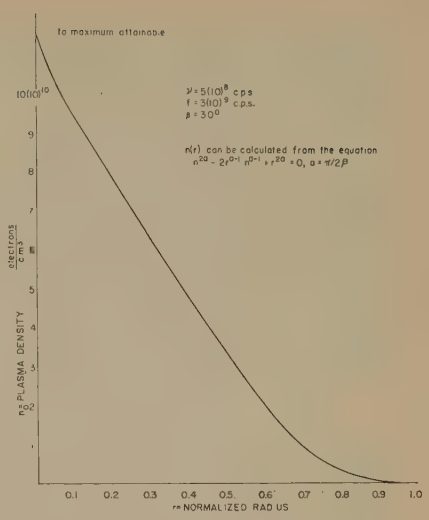

to maximum attainable
ν = 5(10)⁸ cps
f = 3(10)⁹ c.p.s.
β = 30°
n(r) can be calculated from the equation
n²β − 2r^(β−1) n^(β−1) + r^(2β) = 0, α = π/2β
electrons / cm³
n/n₀ PLASMA DENSITY
r = NORMALIZED RADIUS

Figure 5 — Plasma Density as a Function of Normalized Radius (Quasi-Eaton Lens).

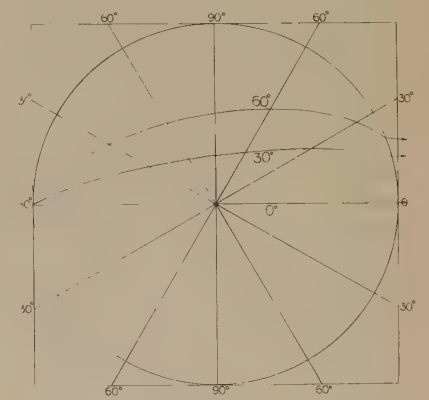


Figure 6 — Paths of Rays in a Quasi-Luneberg Lens.

The index of refraction at quasi-plasma resonance $\left(\dfrac{\omega_p}{\omega_v} = 1\right)$ becomes simply $n = \sqrt{\dfrac{\nu}{2\omega}}$; and in any practical lens $\nu \ll \omega$.

In Figure 6, a plot of the $\alpha_0 = 30°$ (the optimized ray), and $\alpha_0 = 60°$ (one of the extreme rays) rays is presented. The deviation of the 30° ray is, of course, zero, while the deviation of the 60° ray turns out to be about 5.4°. With any reasonable sort of feed, it is seen that the Luneberg-like index of refraction variation allows a simple, fairly accurate solution for the quasi-Luneberg lens.

The path of a ray starting at the

is, $n = \dfrac{c}{V_p} = \sqrt{\dfrac{1}{2}\left\{\left[1-\left(\dfrac{\omega_p}{\omega_v}\right)^2\right] + \sqrt{\left[1-\left(\dfrac{\omega_p}{\omega_v}\right)^2\right]^2 + \left(\dfrac{\nu}{\omega}\right)^2\left(\dfrac{\omega_p}{\omega_v}\right)^4}\right\}}$

surface at $\theta = 180°$ and initially inclined at an angle α to the optical axis is given by the equation

$$2ar^2 = \frac{\phi}{1 - \sqrt{1-\phi}\,\sin\,[2\theta - (270° + \theta_o)]}$$

where $\phi = 4a(1-a)\sin^2\alpha$, and θ_o is the angle between the optical axis and the radius vector from the center to the point of emergence:

$$\theta_o = 90° - \sin^{-1}\frac{2a-\phi}{2a\sqrt{1-\phi}}.$$

A plot of the required plasma density as a function of radial distance is shown in Figure 7.

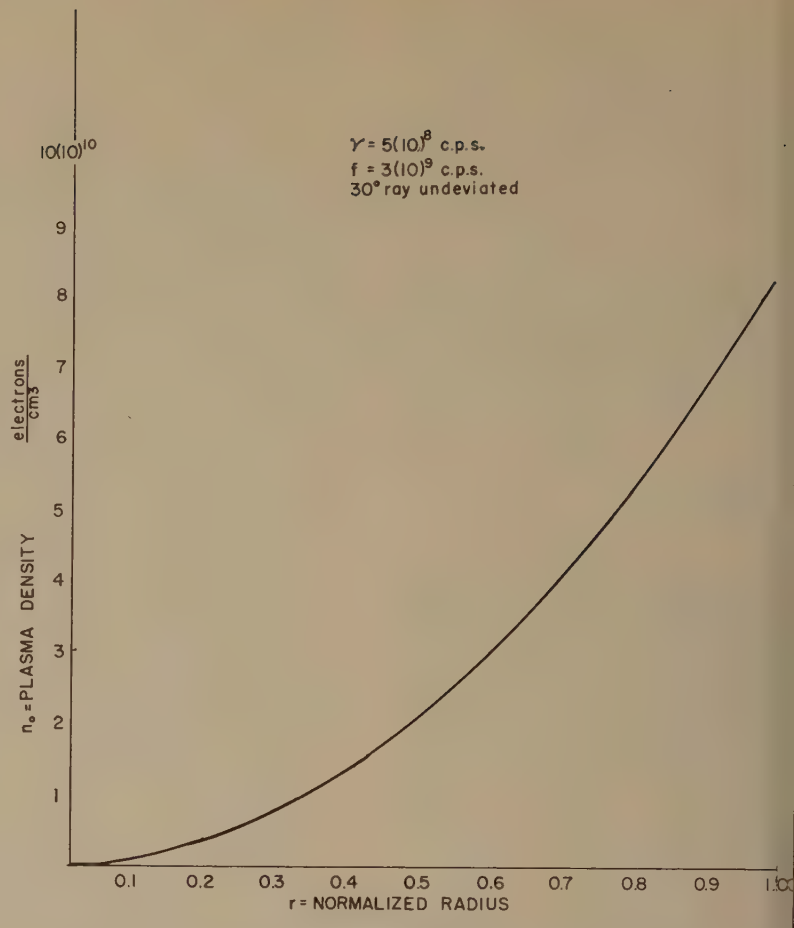


Figure 7 — Plasma Density as a Function of Normalized Radius (Quasi Linear Lens).

VII. CONCLUSIONS

The applications chosen by the authors seemed to them to be representative of the possibilities afforded by the plasma characteristics of variable complex permittivity and variety of generated spatial distributions. A consideration of plasma resonance type scanners should provide adequate background for investigations of scanners employing any type of anisotropic plasma, including the case of cyclotron resonance. One must, of course, have the theoretical and/or experimental ability to deal with electromagnetic boundary value problems of the usual complexity, such as encountered in the case of ferrites within guides. The empirical approach is somewhat easier, as a rule, for complex plasmas than with ferrite bodies, because the density, anisotropy, and spatial distribution function of the plasma are under rather flexible control.

The authors have not yet succeeded in constructing even a theoretical model of a gaseous scanner having simultaneously the important characteristics of low loss, wide bandwidth, and appreciable power handling capacity. Even though the permittivity tensor of any element of gaseous plasma is a function of frequency (and markedly so), the use of peculiar spatial distributions and inhomogeneous fields shows promise in alleviating the bandwidth problem. Various types of anisotropic plasmas can also make it possible to overcome the loss and power handling limitations, under certain conditions. One should not sell short plasma scanners of the general type because of the obvious limitations of the simple, plasma resonance scanners, as presented in this paper.

VIII. ACKNOWLEDGMENTS

The authors wish to express their appreciation to the members of the Melpar Antenna Section for their aid in matters relating to this paper. Individual recognition is due Mr. Kenneth S. Kelleher** and Mr. George G. Chadwick† for special information concerning lenses and slot arrays, respectively.

**President, Aero Geo Astro Corp.
†Aero Geo Astro Corp.

A NEW KLYSTRON amplifier has been developed which has as its starting point the general principle of operation of Varian's externally tuned reflex klystron oscillators. Merely putting two cavities of that type along an electron beam does not result in satisfactory amplification over a useful range of frequency, and in fact can result in attenuation. In order to achieve satisfactory amplification, the coupling window between the internal and external cavities must be a complex, bandpass transformer, thus indicating new microwave fields of study to be investigated.

In the past, externally tuned klystron amplifiers have been tuned by inductive means, such as moving an end wall in a waveguide cavity, whereas this new amplifier is tuned capacitively. The capacitive tuner consists of a screw inserted through a broad wall of the waveguide forming the external cavity. This has resulted in a rugged, easily tuned tube, and one which has very good thermal stability.

The tuning range is six per cent in X-band. At midband, power gains of this two-cavity klystron amplifier as high as fourteen decibels have been obtained, with the mean gain being ten decibels. Saturated power outputs of two to five watts may be obtained with low voltage and current. Possible microwave applications include ground-based uses, but primarily the tube is aimed for service in airborne equipment — either continuous-wave, pulse-modulated, synchrodyned or serrodyned.

A NEW KLYSTRON AMPLIFIER FEATURING CAPACITIVE EXTERNAL TUNING

ROBERT G. ROCKWELL

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INTRODUCTION

To meet the requirements of an airborne, rugged medium-power microwave amplifier, a new design for a two-cavity klystron has been developed which features a novel external tuning mechanism. This tube has been designated the VA-824.[1] Some of the design aims for the amplifier were to have its required gain at low voltage and current, be easily and accurately tunable over a six per cent range in X-band, and be sufficiently rugged and temperature compensated to perform satisfactorily under conditions such as might be expected in missile and aircraft environments. Possible applications include laboratory benchwork, but primarily the tube is aimed for active service in airborne equipment — such as continuous-wave amplification, pulse modulated amplification, and synchrodyne or serrodyne[2] frequency shifting. In the expanding field of continuous-wave radar, for example, may be found such items as ground velocity indicators, missile guidance systems, and doppler navigators.

ELECTRICAL DESIGN

Starting Point

The starting point, from the microwave viewpoint, for the development of the VA-824 was the general principle of coupled-cavity tuning as originally applied to reflex klystrons.[3] This principle was combined with the necessity of at least two cavities along the beam when building an amplifier. To illustrate this principle, Figure 1 shows the tuning curves of a tightly coupled double-tuned cavity, such as used in the VA-824 and the reflex tubes, for example, the VA-210B. The frequency of the internal cavity is fixed and independent of the tuning, which affects only the external cavity. This fixed frequency is indicated by the dashed, horizontal line labeled internal cavity. The external cavity's frequency is tunable and is indicated by the straight, dashed line at a 45° angle.

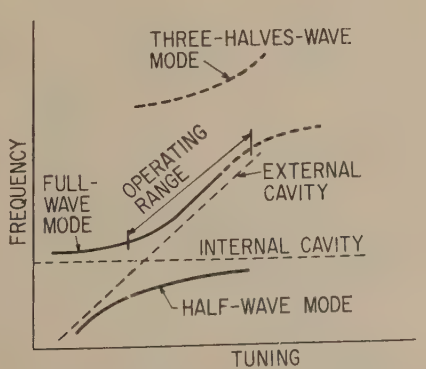


Figure 1 — Tuning Curves for tightly-coupled double-tuned cavity.

Tuning Curves

Because the internal and external cavities are heavily coupled together, the actual tuning curves are as shown by the solid lines, and exhibit the two resonant frequencies that are characteristic of over-coupled, double-tuned circuits. A third resonance at a higher frequency also occurs, however, which involves the coupling network between the internal and external cavities. The useful tuning range is very intimately connected with this coupling network, which imposes an upper limit on the frequency attainable in the full-wave cavity mode to be described below. The lower limit on the tuning range of the full-wave cavity mode is imposed by the half-wave cavity mode. Both the full-wave and half-wave cavity modes tune asymptotically to the fixed frequency of the internal cavity, but at opposite ends of the tuning screw insertion. It should be stated here that the normal operating range of a VA-824 is in the full-wave cavity mode wherein the greatest gain is normally attained.

Cavity Modes

At this point it seems appropriate to define the various cavity mode terms used in the preceding paragraph. A cavity mode, which has one null of the electric field at the

waveguide-coupling iris in the external cavity, and its other null on the other side of the drift tube on the wall of the internal cavity, is defined as a half-wave cavity mode. If there is an intervening null, the resultant mode is termed a full-wave cavity mode. For each additional null the higher-order cavity modes are referred to as three-halves, two-full-wave, five-halves, etc. Since the VA-824 normally operates on the full-wave mode, a null occurs somewhere in the vicinity of the ceramic coupling window, and peak values of the electric field occur nearly at both the gap and the tuning screw. The half-wave spurious mode has an upper frequency limit of about 9.3 kilomegacycles, whereas the three-halves cavity mode, also spurious, has a lower limit of about eleven kilomegacycles. Inasmuch as the VA-824 is driven by an external frequency source, it is not necessary to provide mode suppression means for these two spurious modes as would be required in an oscillator. It is, therefore, possible to achieve some gain in the spurious modes if the drive frequency is adjusted to the frequency of a spurious mode, but this amplification will always be outside the normal operating range.

Figure 2 is a schematic drawing of a tightly coupled double-tuned cavity resonator showing the magnetic and electric field configurations for the full-wave cavity mode. From the electric field sketch it can be seen why the tuning may be likened to capacitive tuning, since the tuning screw is near a peak of the electric field. Hence inserting the tuning screw is like reducing the distance between two plates of a condenser. This results in more capacitance, and thereby a reduction in frequency. As

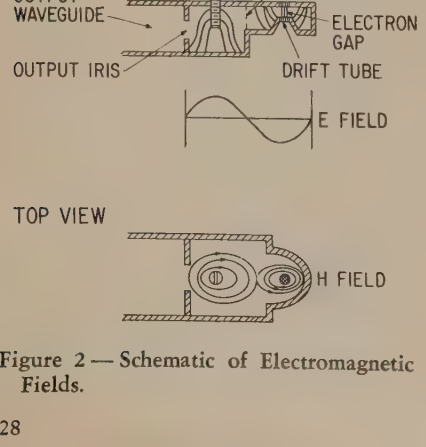


Figure 2 — Schematic of Electromagnetic Fields.

the frequency is lowered, the null in the vicinity of the ceramic window moves away from the drift tube.

This is a major difference from other tube types which are tuned externally by inductive means.[4] In such tubes the tuning is accomplished by physically moving an end-wall of the cavity. Thus the actual distance between the end points of each cavity mode is changed, and additionally the electrical distance between the nulls is also changed. Since this changes the physical wavelength of the cavity modes, it also changes the electrical wavelength, and therefore the frequency is changed.

Coupling Network

The dimensions of the ceramic window and frame were initially chosen based on results of tests which measured the r-f transmission through the window-frame combination mounted transversely to the axis of an X-band waveguide. The dimensions of the window-frame were varied in a series of cut-and-try experiments so as to obtain a maximum of transmission at the midband of the desired operating range. It turned out that this r-f transmission method of obtaining a design was slightly better than a guess would have been. Since the characteristics of the window as mounted in the tube are more those of a complex transformer than those of a simple waveguide transmission device, the bandpass characteristics of the window as mounted in the tube turned out to be of paramount importance.

The problem is that merely putting two externally tuned cavities along an electron beam does not result in satisfactory amplification over a useful range of frequency, and in fact can result in attenuation. For instance, the first tubes had gains of twelve decibels at ten kilomegacycles, but less than zero decibel gain at 9.4 kilomegacycles. Operating data of actual tubes were then used to indicate the changes in the window-frame which were necessary to obtain sufficient gain over the desired six per cent tuning range. A follow-up check on the r-f transmission has shown that the window as mounted in a waveguide has a maximum of transmission which is nearly flat over a band equal to the amplifying tuning range, but located entirely below and adjacent to the tuning range.

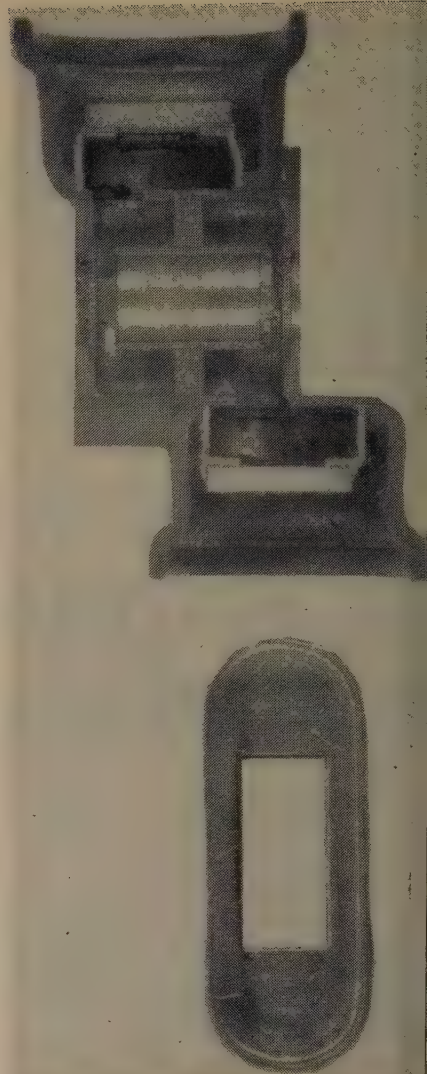


Figure 3 — VA-823 Ceramic Window ar cutaway view of input and outp Internal Cavities.

Cavity Parameters

The internal cavities are of th singly re-entrant type as may be see from the cutaway view in Figure The gap dimensions were such that the operating potential of 750 vol the gap transit angle was about 1 radians. A normalized hole radiu of a single hole of the copper he grid was 0.825 radian. The drift tub radius was 4.6 radians and the bea radius was about 3.75 radians, th corresponding to the beam's fillin about eighty per cent of the dri tube. The drift length between ca ities was about 0.14 of a reduce plasma wavelength, assuming ten p cent beam interception per grid. value less than the optimum 0. reduced plasma wavelength w chosen in order to avoid unduly sa rificing current which would othe wise be useful at the output ga Since space-charge defocusing effec are continually acting to cause th

eam to diverge, it was felt that a onger drift tube would merely result n more beam interception.

uggedness Enhancement

It is of some interest to note how ne electrical design of the tube lends self to ruggedness, which is of great nportance for airborne applications. As mentioned previously, both the nput and output cavities of the VA-24 are of the coupled-cavity type, onsisting of an internal and an external cavity tightly coupled by a arge iris at the vacuum seal. The internal cavity is the evacuated portion nd contains the electron interaction ap, which, because of its rapid tuning properties, is generally a source f microphonic noise. Since the portion of the resonator inside the vacuum does not have to be tuned, however, it has been possible to make the nternal cavity very rugged. The xternal cavity is outside the vacuum nvelope, and since the external cavity is at ambient pressure, a simple, ugged protrusion through one wall orms a convenient tuner. Currently Varian is producing hermetically ealed VA-824's in which the use of n O-ring still permits easy, convenient tuning. The ceramic windows in the coupling networks also erve as rugged vacuum seals. As he external-cavity type of resonator ad been used very successfully by Varian Associates in very rugged reflex oscillators for missile applications, it seemed apparent that an mplifier built similarly should also e useful for missile applications vherein ruggedness was a requirement.

MECHANICAL DESIGN

Starting Point

In designing the tube mechanically o meet the ruggedness requirements, he VA-824 was patterned after Varian's unique integral externally uned reflex klystrons.[5, 6] Since very atisfactory results (especially from nicrophonic and thermal viewpoints) have been obtained from uch brazed-on, external cavity construction, it was without too much repidation that the development of his novel construction for a klystron mplifier was embarked upon.

Microwave Circuitry

Figure 4 is a photograph of a developmental VA-824 which was placed n service in a doppler navigator. This view shows the iris coupling to the input cavity, and the tuning device for the output cavity. The output coupling iris and the tuning device for the input cavity are, respectively, identical. Subsequent modifications to this tube have included mica window seals over the external cavity coupling irises as shown in Figure 5, and O-rings in the tuners. These provide hermetic seals to prevent frequency shifting induced by the change of the dielectric constant of air at high altitudes.

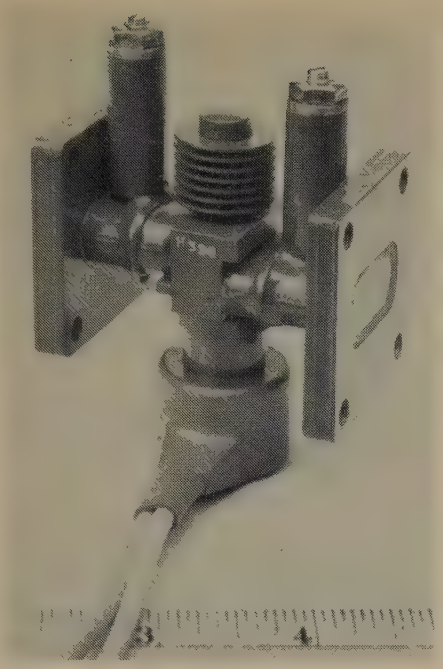


Figure 4 — A developmental VA-824 externally tuned Klystron Amplifier.

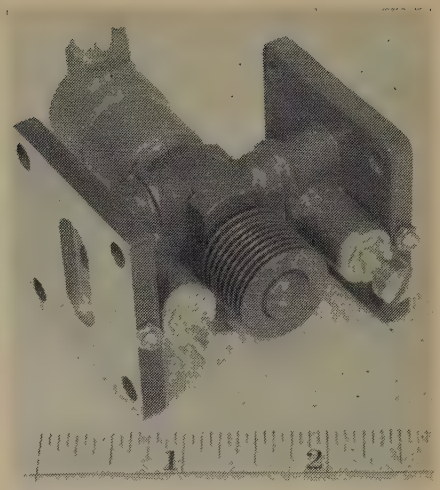


Figure 5 — Hermetically Sealed VA-824.

Figure 6 is a schematic sectional view of the VA-824. The central portion contains an electron gun assembly, two internal cavities with ceramic coupling windows, and a collector with its cooling fins. Note that the internal cavity is rigid-walled and thus does not have, as in a gap-tuned tube, a thin-walled flexible diaphragm which would be sensitive to vibration and also to changes in atmospheric pressure. This central portion is built and pumped separately, then gold-plated, after which two gold-plated external cavities are soldered on, one for the input circuit, and one for the output circuit. The external cavity assemblies consist of the tuners, the input-output

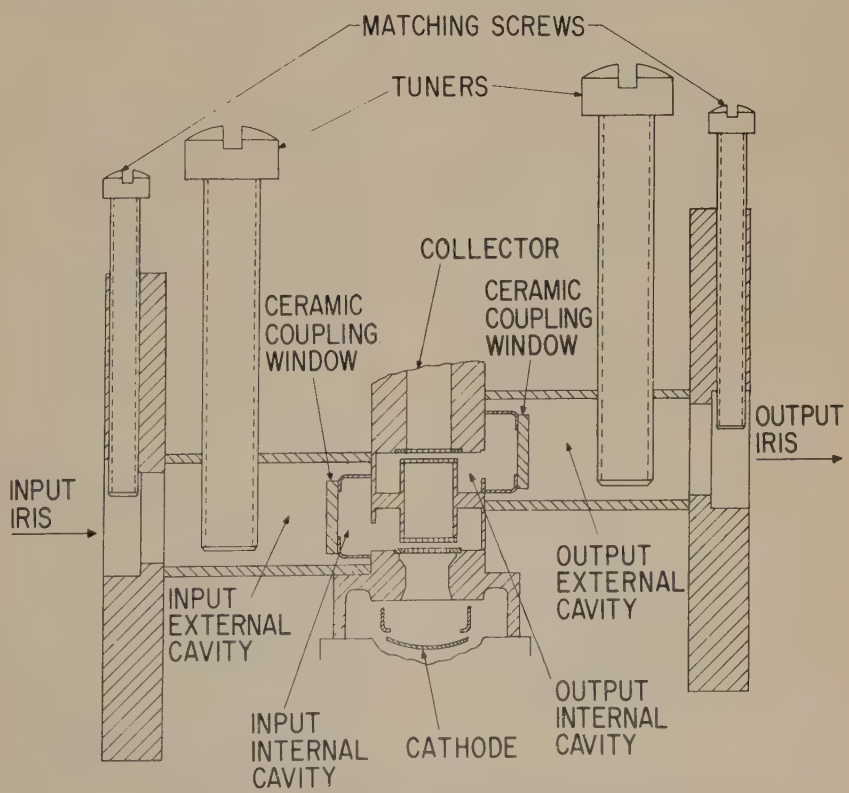


Figure 6 — Schematic Sectional View of the VA-824.

irises, matching screws, and waveguide flanges. After final testing and application of silicone rubber potting, the exterior of the klystron is painted for further environmental protection, such as against high humidity.

Electron Gun

Figure 7 is a schematic of the electron gun as used in the developmental tubes. A pancake heater was held snugly against the back of the cathode button. This type of construction is very rugged and thermally efficient. Also, for enhanced ruggedness, the rest of the gun parts were brazed together. Ceramic, rather than glass, was chosen to further enhance the ruggedness of the mount. A single ceramic ring was used for both the cathode support and the vacuum seal. Besides being simpler and more rugged than conventional ceramic insulators used for cathode support, this high voltage seal is in such a position that material evaporated from the heater will not deposit on it and cause high voltage breakdown from cathode to anode. The oxide-coated cathode was aligned with the anode hole and spaced therefrom by means of a cup between the ceramic and an accurately machined shoulder in the anode. Since the tube is designed for high-altitude airborne applications, the cathode and heater connections are potted in a silicone rubber compound to prevent voltage breakdown and corona at high altitudes.

The gun in both cases, however, has a designed perveance of 2.4×10^{-6} amperes/volt$^{3/2}$. The convergence is probably less than two in spite of any ion focusing because of the diverging lens action of the anode hole and the effects of the grids at each end of the drift tube. A transmission efficiency of typically 65 per cent is obtained through the four copper, hexagonal-honeycomb grids and the 0.185-inch diameter drift tube which is 0.330 inch long. At the designed operating potential of 750 volts, these conditions correspond to a power density in the beam of about 240 watts per square centimeter which is safely below the power density which will melt the copper grids. Experience has indicated that the particular grids and thermal path used in this design cause the grids to melt at about a power density of 900 watts per square centimeter.

Ceramic Window

The use of ceramic for the vacuum windows, rather than mica sealed in

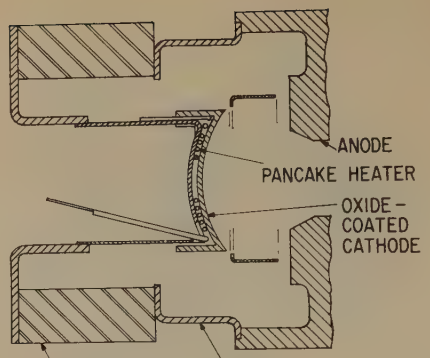


Figure 7 — Schematic for Electron Gun.

place by glass as in the Varian V-27, was very desirable for a number of reasons. Chief of these was the fact that if glass were not used at all, the tube could be baked to a much higher temperature on the pump, thus producing a cleaner tube with longer life and greater reliability.[7] Further benefits to the tube are (1) high resistance to mechanical and thermal shock, (2) ability to operate at high body and/or ambient temperatures, and (3) improved mechanical design.

The ceramic window, at the time of the beginning of the development, was an innovation for use in an externally tuned klystron of the type described herein, as may be realized when compared with other externally tuned reflex klystrons, most of which used mica windows. In developing the mechanical features of this new ceramic window design so as to achieve the benefits of higher bakeout temperatures, the first step was to make an estimate of the probable window dimensions. This estimate was decidedly influenced by the mechanical considerations of how and where the window could be physically placed in the tube. The steps leading up to the final design were discussed earlier in the section on the electrical design.

The final design of the ceramic window and mounting frame of the VA-824 may be seen by referring back to Figure 3. From the two views it can be seen that the length of the ceramic is several times its height. This shape ratio, along with the shortness of the flexible portion of the mounting frame, sets up severe stresses. Because of the lack of time on the developmental contract, we chose a metal for the mounting cup which had nearly the same coefficient of expansion as the ceramic and hence the effects of the severe stresses were minimized. The metal chosen was platinum. Commercially available VA-824's were subsequently modified to permit the use of kovar mounting cups.

TEST RESULTS

Vibration

Environmental tests to check the ruggedness of the tubes were made as soon as tubes with sufficient gain over the tuning range were obtained. As mentioned earlier, this required the appropriate bandpass characteristics in the coupling network between the internal and external cavities. Vibration testing of the tubes was carried out in the manner of a component test rather than a system test, i.e. the tube was mounted by both flanges in a highly rugged tube support, as shown in Figure 8. A rugged tube mount eliminates the possibility of g-amplification which will result with the use of a flimsy mounting bracket often encountered in practice in an airborne system which has weight reduction as a further aim. This is the distinction between a component test and a system test.

The rugged tube support was made of several half-inch thick pieces of tempered aluminum bolted together. Thus it could be adjusted to mate evenly and snugly with both the input and output flanges, even though they might not be exactly parallel without stressing the external cavities. Accelerometers mounted on the rugged tube support showed that there was no g-amplification. Thus the tube mount shook the same as the shaker table.

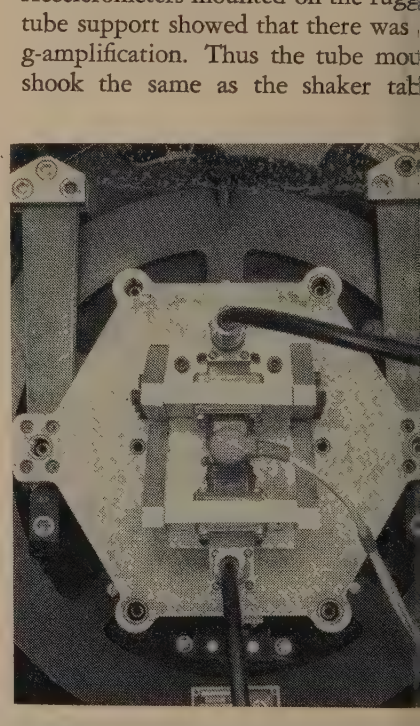


Figure 8 — VA-824 in Vibration Test Mount.

vhich was vibrated at ten g's from 0 — 1000 cycles per second. Vibration in the planes (1) parallel to the eam axis and perpendicular to the xis of the waveguide, and (2) perendicular to the beam axis and perendicular to the waveguide axis realed only two slight peaks of phase-nodulation noise — these in the range f 700 to 950 cycles per second. These eaks were of the order of fifty deciels below the carrier signal; the genral level was sixty-five decibels down. Amplitude-modulation noise did not xceed phase-modulation noise at any ibration frequency.

Temperature Compensation

As a further consequence of the external-cavity type construction, it was ossible to design the tube with good hermal conductivity from the internal ources of heat (where the electron eam is intercepted by the grids and he drift tube wall), to the exterior vhere cooling takes place. Cooling ins are built on the collector so that ir-cooling may be used, but in addiion a substantial amount of heat is onducted away via the external cavies by the attached microwave plumbng. Thus, the klystron reaches therial equilibrium rapidly and thermal ompensation is easily achieved in nost tubes.

The temperature compensation nechanism built into the evacuated ortion of the VA-824's is the same as hat which is standard for Varian's oupled-cavity reflex oscillators, and naintains the resonant frequency of he cavities within desired bounds in nost cases. In this design the internal avity is compensated by making the lrift tube of molybdenum while the est of the cavity is made of copperlated steel. As the klystron warms p because of an increase in the ambient temperature, the difference in xpansion between the molybdenum lrift tube and the copper-plated steel avity causes the gridded gap spacing o increase. The resulting decrease in apacity counteracts the increase in the nductive portions of the cavity and ends to keep the frequency constant. n actuality the resultant frequency hange has been negative, that is, the requency of peak amplification has lecreased with an increase of temperaure at the rate of about —100 kilocycles per degree centigrade.

For those tubes in which the frequency change with temperature did not stay within the desired bounds, it was found possible to use a bimetal tab on the end of the tuning screw in the external cavity. As the tube warms up, the bimetal tab contracts, thus shortening the effective length of the tuning screw and thereby increasing the frequency because of the reduced capacitance. In nearly all tubes where used this has still resulted in negative frequency change, but in a few tubes it has resulted in a positive frequency change. In all cases where needed, however, the bimetal tabs have kept the frequency change within the desired bounds.

In amplifiers, however, it is not too meaningful to speak in terms of frequency change, since the driving frequency presumably is constant. In the more meaningful terms of change in gain at the desired operating frequency, it has been possible to achieve temperature compensation of less than 0.025 decibel per degree centigrade over a thirty degree centigrade range. That is, with the tube tuned under ambient conditions, the ambient temperature may change $\pm 30°C$ and the loss of gain will be a maximum of 0.75 decibel. This loss in gain is due to the fact that with detuning caused by a change in the ambient temperature, the amplification then occurs, so to speak, on the side of the amplifier's gain vs. frequency mode, since the drive frequency, as stated, has not changed with this change in the ambient temperature affecting the VA-824. It is interesting to note, however, that the gain at the new frequency for peak amplification has been within 0.1 decibel of the gain under the initial ambient conditions. The reason for any loss at all in peak gain is that the various thermal effects are slightly different in each cavity, possibly because beam interception on the grids causes different heating in each cavity. Thus the input and the output cavities do not detune exactly to the same new frequency when the ambient temperature is changed, and thus the gain is slightly less.

At the design operating potential of 750 volts, it has been found that without air cooling the body temperature stabilized at 100°C above room temperature. It should be stressed that the tube was connected to waveguide plumbing at both the input and output flanges. Thus the tube could be used up to an ambient temperature of 100°C without air-cooling and still not exceed the recommended maximum tube operating temperature of 200°C. Some klystrons with ceramic seals at Varian Associates have been operated at ambient temperatures of between 500° and 600°C.[8] At the present time, however, the life of such tubes is limited by oxidation of external metal portions of the vacuum envelope.

Gain

It has been found that a gain at midband as high as fourteen decibels is attainable with eleven decibels at the tuning range end-frequencies 300 megacycles on either side. Figure 9 is a plot of the synchronously-tuned continuous-wave power gain in decibels vs. frequency. A typical VA-824 would have a gain of nearly ten decibels, ± one decibel, across the tuning range of 9.4 to ten kilomegacycles. Because of the characteristics of external cavity tuning, relatively less energy is stored in the external cavity at the extremes of the tuning range, which thereby results in less gain at 9.4 and ten kilomegacycles than 9.7 kilomegacycles. Further, the use of external tuning cavities leads to a loss of shunt impedance due to energy storage in regions other than the grid gap where the beam interacts with the field. The coupling network between cavities, however, acts along with the coupling iris to the waveguide in such a way as to increase the coupling of power to the waveguide. As a consequence of these various factors, it can be seen from Figure 9 that the maximum gain occurs in the center of the tuning range, and that the maximum gain is nearly two decibels greater than the minimum gain. It is thought that the VA-824 with the gain of fourteen

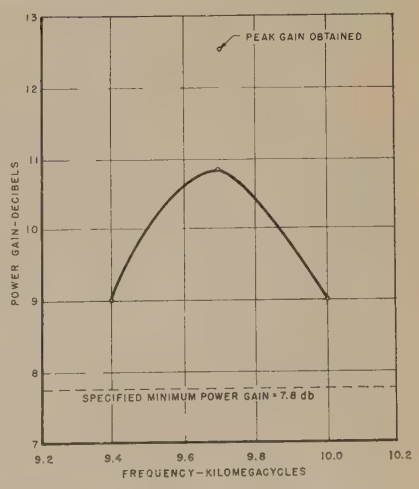


Figure 9 — Power Gain vs. Frequency for a typical VA-824.

decibels must have had, in addition to an excellent fabrication of the gun parts, an excellent beam alignment, and consequently excellent transmission with maximum utilization of the electrons.

Power Output

As the development customer wished the tube to operate at low voltage, data have mostly been taken at the specified beam potential of 750 volts. The saturated output power at 750 volts has statistically varied on a tube-to-tube basis from two to four watts with an input drive power of typically one-half watt.

Figure 10 shows representative data of power input vs power output at a drive frequency of 9.8 kilomegacycles as a function of applied beam potentials. It can be seen that the low-level gain does not increase above that which can be obtained at 700 volts. The curves for each beam voltage follow the usual J_1^2 curve [9] for klystron amplifiers. For several of the lower beam potentials the available drive oscillator, a Varian VA-58, had sufficient power to drive the output power of the VA-824 through the first null and to the second peak of J_1^2. At a beam potential of 400 volts it was possible to drive to the third and fourth peaks of J_1^2.

The data in Figure 10 were taken up to a beam potential of 1000 volts with a resultant saturated output power of slightly over five watts. The efficiency was about eight per cent which is very comparable to that of conventional two-cavity klystron amplifiers. For even higher output power up to about eight watts it is possible to process the tubes on the pump for operation up to about 1250 volts without too much danger of grid-burnout.

SIZE AND WEIGHT

No magnetic focusing is necessary for the operation of a VA-824, and hence the use of a large and heavy magnet is avoided. For an airborne application this will result in a significant weight reduction and space saving as compared with other types of amplifiers which might have to rely on magnetic fields in order to focus an electron beam. Not only is it not necessary for the aircraft to carry aloft the magnet, but best of all there is no need to have a power supply which would be required to operate a focus solenoid. The weight of the VA-824 is about 8½ ounces. Its overall dimensions are approximately 1½ × 2 × 3 inches, or about nine cubic inches. This nearly represents its minimum size and weight.

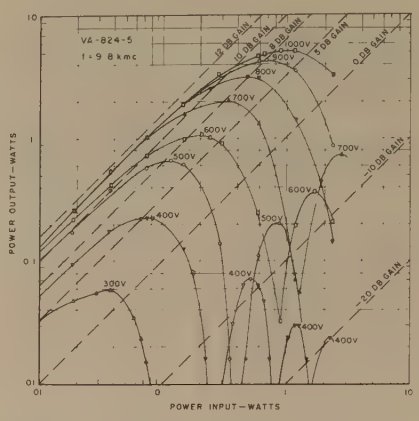


Figure 10 — Power Output vs. Input for a VA-824 tuned to 9.8 Kmc. Data taken as a function of Beam Voltage.

CONCLUSIONS

The design of an all-ceramic klystron to meet the objectives of a rugged medium-power amplifier has resulted in tubes which have more than the customer's specified gain of about eight decibels over a six per cent tuning range in X-band. This has been achieved by adapting known techniques of external cavity tuning for oscillators to a new use for amplifiers. This new use has only been successful when in addition there has been provided a satisfactory bandpass network between the internal and external cavities. It is not meant to be implied that there is a unique network which accomplishes this. But for the particular distance of the ceramic from the gap and the thickness of the ceramic, there did appear to be a unique shape and size of the iris in the window mounting frame. It is thus felt that this coupling network has been primarily responsible for the successful culmination of this project which has resulted in this new klystron amplifier featuring the first use of capacitive external tuning.

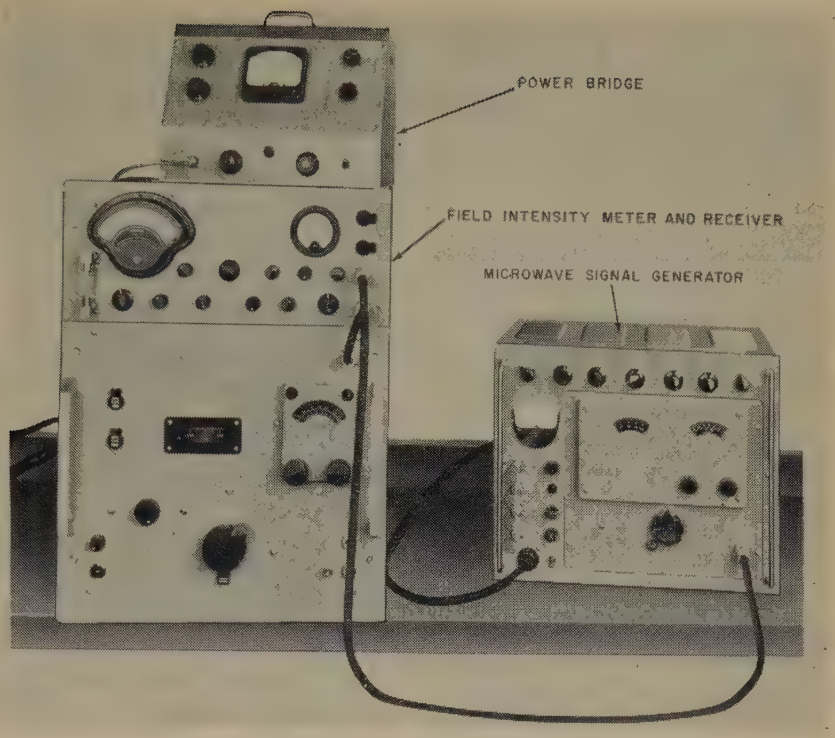
Accordingly, it may be stated that the VA-824 is a satisfactory tube for many applications, especially those relative to missiles and aircraft where vibration is encountered. Applications where the tubes may be used include continuous-wave amplification, pulse-modulation, synchrodyning or serrodyning. The power requirements have been kept low; thus, temperature compensation has been possible to achieve over a useful range of ambi temperatures. The low power requi ments in turn should result in li weight power supplies as are desira for airborne applications. Also si the tubes operate without the necess of magnetic focusing, it is not nec sary for the aircraft to carry aloft heavy beam focusing magnet.

Hence a new klystron amplifier appeared on the microwave scene, a it is believed that it would be possi to extend the principle of operati to other frequency ranges besides band. Also by modifications to grids it is quite likely that high power levels could be achieved. F ther, multi-cavity tubes could be veloped so as to obtain higher gai Accordingly designers of rugged, a borne systems have available a n relatively inexpensive electron dev at their disposal which combines lig weight, ruggedness, and easy, conve ient tuning.

REFERENCES

1. Patent Pending.
2. R. C. Cumming, "The Serrody Frequency Translator," Proc. I Vol. 45, pp. 175-186, February, 195
3. T. Moreno, "Characteristics of M ern External Tuning Cavity Ref Klystrons," Oral Presentation at WI CON, Los Angeles, California, A ust, 1956.*
4. R. G. Rockwell, "Wide-Range K-Ba Klystrons," Published in Records the Electronics Components Conf ence, Los Angeles, California, M 26-27, 1955.
5. T. Moreno, op. cit.
6. W. G. Abraham and F. L. Salisbu "A Rugged 8-Millimeter Reflex K stron," Paper presented at WESCO Los Angeles, California, Augu 1956.*
7. C. Pearsall, "Ceramics in Microwa Tubes," Paper presented at 7th Reg IRE Conference, San Diego, Calif nia, April 25, 1957.*
8. C. Pearsall, op. cit.
9. First Order Bessel Function of First Kind.

*Reprints available from Varian As ciates.



gure 1 — Measuring noise figure of the Polarad FIM Field Intensity Meter and Receiver with a Signal Generator.

MICROWAVE NOISE FIGURE MEASUREMENTS USING A SIGNAL GENERATOR

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INTRODUCTION

The noise figure of a receiver is a easure of the amount of internal ise generated by the receiver. By finition, it is the ratio of the total ise power output of the receiver as mpared to the noise power output at would be present if the receiver ere theoretically perfect, i.e., one hich generated no internal noise.

An alternative definition of noise gure is given by the following re-tionship:

$$F = \frac{\textit{Signal-to-Noise Power Ratio of Ideal Receiver}}{\textit{Signal-to-Noise Power Ratio of Actual Receiver}}$$

he two definitions may be seen to rrespond. If the signals delivered the two receivers are identical, we tain

$$F = \frac{S/N_i}{S/N_a} = \frac{N_a}{N_i}$$

where

S is the signal delivered by each receiver,

N_i is the noise output of, or noise generated by, the ideal receiver, and

N_a is the noise output or noise generated by the actual receiver.

Noise figure is expressed as a power ratio or, more commonly, in decibels. The "noiseless" receiver, if it were to exist, would have a noise figure of one, or 0 db. Most modern microwave receivers have noise figures ranging from 6 db to 30 db.

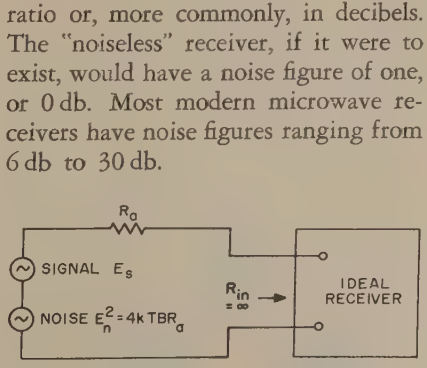


Figure 2 — Schematic representation of ideal receiving system. The ideal receiver is one generating no noise.

Since no internal noise is generated by an ideal receiver, the thermal agitation noise of the receiving antenna is the only noise which appears at either the input or output terminals of the receiver. The ideal receiver, therefore, must have an infinite input resistance, since otherwise thermal agitation noise in the input resistance would constitute a noise source within the receiver. This requirement enables the ideal receiver to have the highest possible signal-to-noise ratio.

The equivalent circuit of an ideal receiving system is shown in figure 2. The noise voltage produced in the antenna radiation resistance is given by the relationship for thermal agitation noise voltage in a frequency independent resistor, which is

$$E_n^2 = 4R_akTB$$

where

R_a is the antenna radiation resistance in ohms,

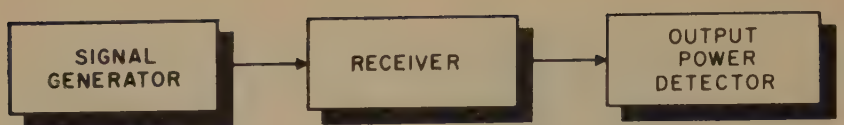


Figure 3 — Arrangement for measurement of Noise Figure with a Signal Generator.

k is Boltzmann's constant, 1.38×10^{-23} joules per degree Kelvin,

T is the effective temperature of the radiation resistance in degrees Kelvin, and

B is the receiver bandwidth in cycles per second.

The signal-to-noise ratio of an ideal receiver is the same at the output terminals as at the input terminals of the receiver, since no noise is generated by the receiver. The signal-to-noise ratio of an ideal receiving system is, therefore, the signal-to-noise ratio at the output of the open-circuited antenna, or

$$\text{Signal-to-noise power ratio of ideal receiver} = \frac{E_s^2}{E_n^2} = \frac{E_s^2}{4R_a kTB}$$

COMPARISON OF SIGNAL GENERATOR AND NOISE GENERATOR

Noise figure may be measured by use of either a noise generator or a signal generator. Noise generators are more accurately calibrated than signal generators and employ direct measurement methods. Signal generators find application when noise generators are not available and when they are preferred to noise generators for one of the following reasons: A noise generator cannot be used to measure noise figures above 20 db without resorting to complex procedures where an i-f output from the receiver is fed to auxiliary equipment. With a signal generator measurements can be made over a greater frequency range than with a noise generator and less error is introduced due to spurious responses since the signal generator operates at a single frequency.

NOISE FIGURE MEASUREMENT OF A MICROWAVE RECEIVER

The basic arrangement of equipment for measurement of noise figure with a signal generator is shown in figure 3. The measurement technique requires the introduction of a known amount of power and a comparison of the resulting output with that which existed before the introduction of the signal.

In order to find the noise figure by means of a signal generator it is first necessary to determine the sensitivity and the noise bandwidth of the receiver.

Sensitivity

The method of measuring the sensitivity of a receiver depends on whether a continuous wave or a pulsed signal is applied to the receiver. The procedure when using a continuous wave signal is as follows:

Sensitivity Measurement Using CW Signal

(1) Set up the equipment as shown in figure 3. Any convenient power measuring device may be used as the output power detector. It is connected to the output of an i-f stage of the receiver, where sufficient signal can be obtained for monitoring.

(2) With no signal input, set a convenient reference level on the power indicator by means of the receiver gain control.

(3) Add a signal from the signal generator. Increase this input power until the indicator shows that the output power has doubled (increased by 3 db). The generator will now read directly the sensitivity of the receiver.

If an accurate power meter is not available for direct power measurement, any indicator together with a calibrated i-f attenuator may be used. The attenuator is inserted between the receiver and the indicator. By adding three db of attenuation to the circuit after a signal is added to the receiver noise, and adjusting the signal to return the indicator to the position it had with noise only, a direct reading of sensitivity will be obtained from the signal generator.

Sensitivity Measurement Using Pulsed Signal

The following procedure is used with a pulsed signal:

(1) Set up the equipment as shown in figure 3. An oscilloscope must be used as the power indicator. It is connected to the last i-f stage of the receiver.

(2) With receiver noise only, set up a convenient level of deflection on the oscilloscope screen.

(3) Add a signal from the signal generator. Increase this input power until the signal deflection is equal to the noise deflection as shown in figure 4. This is known as tangential sensitivity. Tangential sensitivity has been observed to correspond to a signal-to-noise ratio of 8 db. It will be shown that sensitivity corresponds to a signal-to-noise ratio of 0 db. Therefore subtract 8 db from the signal generator reading. The resulting figure will be the receiver sensitivity.

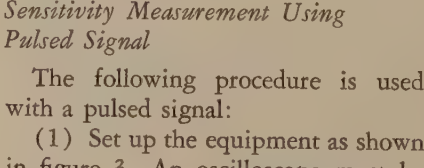


Figure 4 — Tangential Sensitivity.

Bandwidth

Receiver noise bandwidth may conveniently be determined by either of two methods. The same arrangement as shown in figure 3, is used for both.

The following is the first method:

(1) Vary the frequency of the signal over the useful channel.

(2) Note the maximum response.

(3) Vary the frequency until the half power points (—3 db) are located. The difference in frequency between the two half power points is the 3 db bandwidth.

(4) Convert to receiver noise bandwidth using the graph in figure (This figure assumes synchronously tuned cascaded stages.)

The second method, which has the advantage of not requiring an accurately calibrated power indicator, is identical to the first with the exception of step 3. Instead of varying frequency increase the generator output power till the indicator shows an increase of 3 db. Then vary the frequency to the points at which the indicator returns to its original position are found. The difference in frequency between these two points is the 3 db bandwidth.

Step 4 is required because it is extremely difficult to measure noise bandwidth, which is defined by the relationship

$$B = \int_0^\infty \frac{A^2\, df}{A_o^2}$$

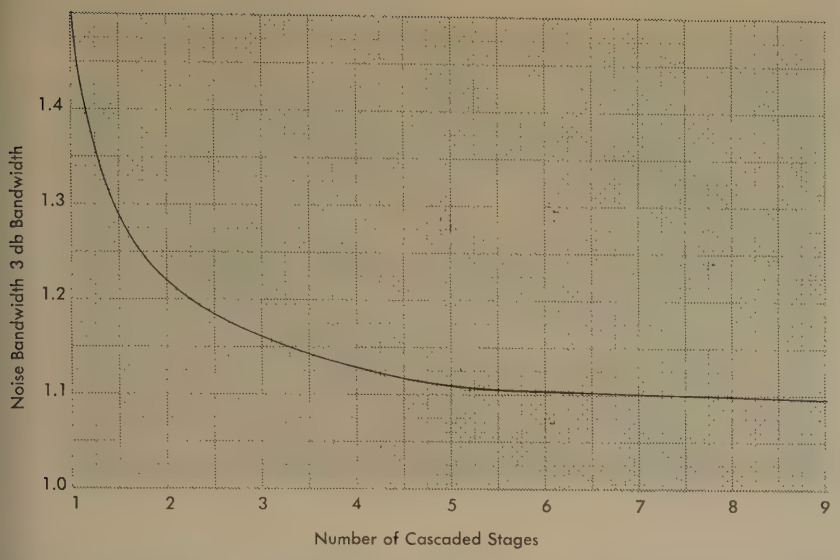
where

A is the relative voltage gain of the system,

A_o is the maximum value of A, and

f is frequency.

Therefore, 3 db bandwidth is measured and converted to noise band-



gure 5 — Effective Noise Bandwidth normalized with respect to the 3 db bandwidth for Synchronously Tuned Cascaded Stages.

idth. Synchronously-tuned cascaded ages present the maximum ratio be- veen noise bandwidth and 3 db ndwidth. For any other situation the tio curve will lie below that shown figure 5 for synchronous tuning. herefore, an error would result if this irve were used for non-synchron- usly-tuned stages. This error can be en to be

$$\% \text{ Error}_{max} = (B_{sn} - 1)\ 100$$

here B_{sn} is the normalized noise ndwidth for synchronously - tuned ages, and

B_{an} is the actual noise bandwidth. he maximum possible error is, there- re

$$\% \text{ Error}_{max} = (B_{sn} - 1)\ 100$$

The relationship which gives the tio of noise bandwidth to 3 db band- idth, and therefore of which figure 5 a plot, is

$$\frac{B}{B_{3db}} = \frac{1 \cdot 3 \cdot 5 \cdot 7 \cdots (2N-3)}{2 \cdot 4 \cdot 6 \cdot 8 \cdots (2N-2)} \times \frac{\pi}{2} \Big/ \sqrt{2^{1/N} - 1}$$

NTERPRETATION OF RESULTS ND FINAL DETERMINATION OF NOISE FIGURE

By doubling the power output of e receiver so that signal plus noise ower is equal to twice the noise ower, a signal-to-noise ratio of one obtained for the receiver under test. he noise figure of the receiver is then ven by

$$= \frac{\textit{Signal-to-Noise Power Ratio of Ideal Receiver}}{\textit{Signal-to-Noise Power Ratio of Receiver Under Test}}$$

$$F = \frac{E_s^2}{4R_a kTB}$$

, represents the open-circuit voltage of the signal generator. The output voltage of the signal generator, E_o, which is the sensitivity in this instance, is related to E_s by the expression

$$E_o = E_s \left(\frac{R_{in}}{R_r + R_{in}} \right)$$

where

R_{in} is the resistance looking into the input terminals of the receiver with the signal generator disconnected, and

R_r is the internal resistance of the signal generator, and may be substituted for the antenna radiation resistance of the ideal system in the relationships which have been given.

The noise figure of the receiver then becomes

$$F = \frac{E_o^2 \left(\frac{R_r + R_{in}}{R_{in}} \right)^2}{4R_r kTB}$$

The receiver is usually matched to the signal generator and therefore R_{in} is equal to R_r. The relationship for noise figure is then

$$F = \frac{E_o^2}{R_r kTB} = \frac{P_o}{kTB}$$

Noise figure, expressed in decibels, is given by the relationship

$$F_{db} = 10 \log F = 10 \log P_o - 10 \log (kTB)$$

Figure 6 is a family of curves which are a plot of this relationship for various bandwidths. A 50-ohm matched input system is assumed.

It can therefore be seen that after sensitivity and noise bandwidth have been determined, the noise figure can be obtained directly from figure 6.

Illustrative Examples

The following examples illustrate the use of figures 5 and 6 in the determination of noise figure:

Example 1: Using a cw signal, the sensitivity of a six-stage synchronously cascaded receiver is found to be —80 dbm. Its 3 db bandwidth is 2.7 mc. Figure 5 shows that the receiver noise bandwidth normalized with respect to the 3 db bandwidth is 1.1. Therefore the noise bandwidth is 3 mc. Using figure 6, the noise figure is found to be 29 db.

Example 2: Using a pulsed signal to measure the sensitivity of a four-stage synchronously cascaded receiver, a generator reading of —79 dbm is obtained. Subtracting 8 db from this figure, the sensitivity is found to be —87 dbm. In accordance with figure 5, a 3 db bandwidth of 1.33 mc gives a noise bandwidth of 1.5 mc. Using figure 6 the noise figure is found to be 25 db.

NOISE FIGURE OF A MICROWAVE AMPLIFIER

The noise figure of a microwave amplifier may be ascertained by an ex-

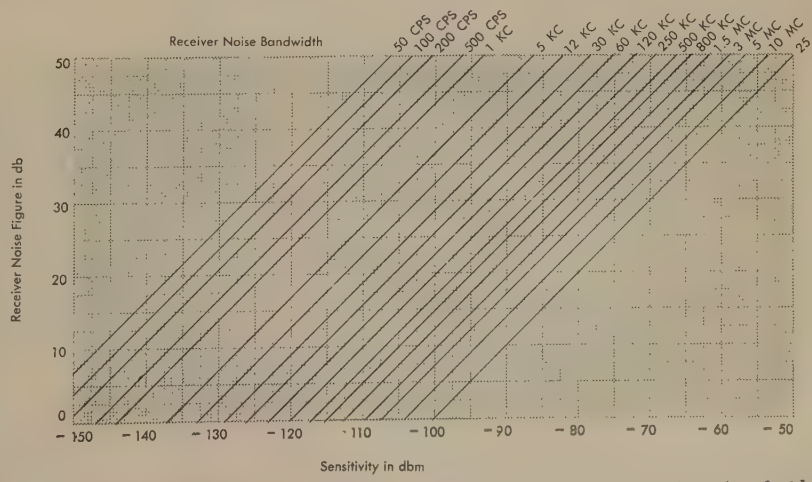


Figure 6 — Receiver Noise Figure vs. Sensitivity for various receiver bandwidths.

Figure 7 — Arrangement for measurement of the gain of a Microwave Amplifier.

tension of the measurement techniques described for the microwave receiver. The following procedure can be followed:

(1) Set up the equipment as shown in the block diagram of figure 7, in order to determine the gain, G, of the amplifier.

(2) Adjust the output signal of the generator to give a convenient reference level above noise on the receiver meter.

(3) Remove the amplifier from the circuit.

(4) Increase the output signal of the generator until the receiver meter returns to its original position. The gain of the amplifier is equal to the difference in the two output settings of the signal generator.

(5) Determine F_R, the noise figure of the receiver, by one of the methods described previously.

(6) Determine F_0, the noise figure of the system consisting of the amplifier together with the receiver, by one of the methods described previously for measuring the noise figure of a receiver.

(7) The noise figure of the amplifier, F_1, can be determined from the following formula:

$$F_1 = F_0 - \frac{F_R - 1}{G}$$

Figure 8 is a plot of this relationship and may be used to determine the noise figure of the amplifier directly. The procedure for the use of this figure is illustrated in the following example:

Example 3: Given an amplifier gain of 11 db, a receiver noise figure of 20 db, and an over-all noise figure of the system of 15 db, find $\frac{F_R - 1}{G}$ by following the F_R line (20 db) to its point of intersection with the G line at 11 db, read on the right hand vertical scale. The noise figure of the amplifier is found by following the line $\frac{F_R - 1}{G}$ (0.8) until it intersects with the over-all noise figure line F_0 (15). The point of intersection determines the noise figure of the amplifier to be 13.5 db from the F_1 curves.

SOURCES OF ERROR

A brief review of inaccuracies that may be introduced during these procedures is described in order to serve as a guide in performing these measurements more satisfactorily.

The first possible source of inaccuracy is the signal generator. The error in noise figure introduced by an inaccurate output reading of the generator will equal the error in the generator reading. Thus, if the generator were to read —75 dbm when actual power output was —77 dbm, there would be an error of 2 db in the noise figure.

When using an oscilloscope, certain approximations are made, which are a source of error. The signal that raises the observed noise by its own amplitude is assumed to be 8 db. Also, results will vary with different operators and with the same operator at different times due to the human factors involved in observing an oscilloscope display.

Other errors may also be introduced in the determination of noise bandwidth. It has been shown that the assumption that the stages of the receiver are synchronously tuned may lead to a small error in noise figure. A more accurate method of computing noise bandwidth involves integrating the frequency response curve of the receiver.

CHOICE OF SIGNAL GENERATOR

A microwave signal generator f use in noise figure measurements m be carefully selected. A frequen range of at least two to one is des able. The attenuator should have range great enough to enable it to used in the measurement of both hi and low noise figure equipment. Acc rately calibrated frequency and pow outputs are essential. The output i pedance should not vary from its no inal value.

The generator must be stable a produce a minimum of incidental A and FM. It should have flexible mod lation characteristics and be able produce both narrow and broad puls at a widely variable repetition rat

These suggestions and procedur are offered to the microwave engine as an aid to the better understandi and execution of microwave measu ments.

REFERENCES

Goldman, H. L., *Frequency Analysis, Mo ulation and Noise.* New York: McGra Hill Book Company, Inc., 1948.

Lebenbaum, Matthew, "Measurement Noise Figure," *Handbook of Microwa Measurements,* ed., Moe Wind. Broo lyn, N.Y.: Polytechnic Institute Brooklyn, Microwave Research Institu 1956.

Montgomery, Carol G., ed., *Technique Microwave Measurements.* New Yo and London: McGraw-Hill Book Co pany, Inc., 1947.

Seidler, Sanford W., *The Measurement Receiver Noise Figure.* Long Island Ci New York: Polarad Electronics Cor ration, January, 1950.

Van Voorhis, S. N., ed., *Microwave R ceivers.* New York, Toronto and Lo don: McGraw-Hill Book Company, In 1948.

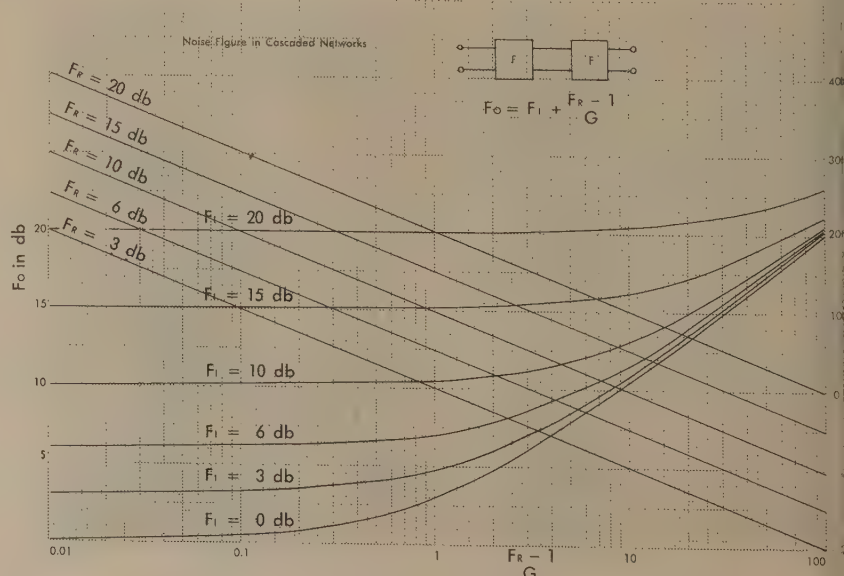


Figure 8 — Noise Figure of a Microwave Amplifier.

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ged construction. Quick, easy inspection and servicing.
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every application, 950 to 21,000 mc.

odel	Frequency Range	Power Output
G-1	950 to 2,400 mc	0 dbm (1 milliwatt) to —127 dbm, directly calibrated
G-2	2,000 to 4,600 mc	
X	4,200 to 8,000 mc 6,950 to 11,000 mc	
G-34	4,200 to 11,000 mc	
K	10,000 to 15,500 mc 15,000 to 21,000 mc	+10 dbm (10 milliwatts) to —90 dbm

MICROWAVE POWER SOURCES—1,050 to 17,500 mc.

power output: 14 to 700 milliwatts depending on fre-
ncy. **Modulation:** Internal square wave or external FM
square wave.

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Generates CW, FM, internal pulse, internal square wave. Or can be externally modulated.

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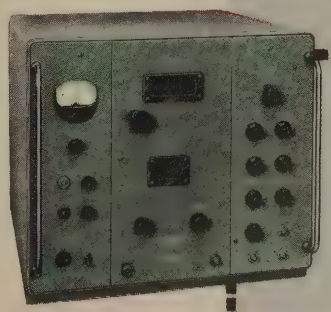
Pulse repetition rate: adjustable from 10 to 10,000 pps.

Pulse width: adjustable from 0.2 to 10 microseconds.

Linear sawtooth internal FM modulation, 10 to 10,000 cps, 5 mc minimum frequency deviation.

Internal or external, pulse or sine wave synchronization.

*Models MSG-34, PMX and PMK



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MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements."

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POLARAD ELECTRONICS CORPORATION

Please send me complete specifications for:

☐ Microwave Signal Generators,
_____ to _____

☐ Microwave Power Sources,
_____ to _____

My application is: _____

Name _____

Title _____ Dept. _____

Company _____

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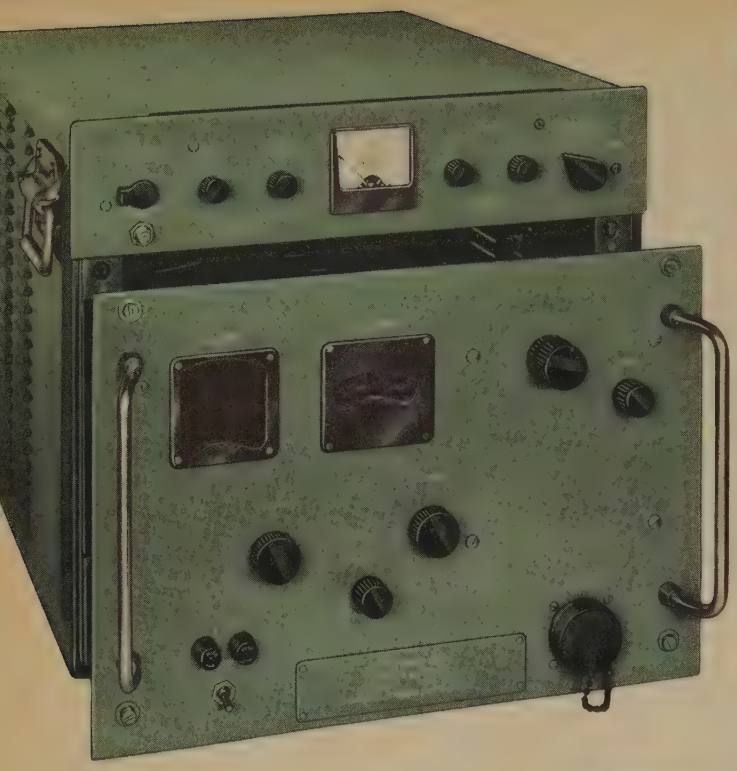
MICROWAVE GENERATORS

18,000 to 50,000 mc

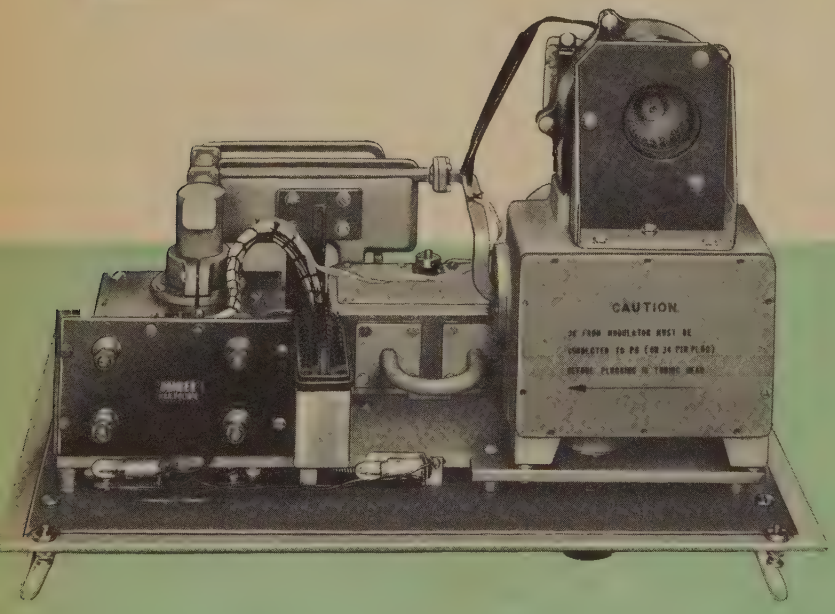


MICROWAVE SIGNAL GENERATORS
18,000 to 39,000 mc

7 interchangeable plug-in tuning units
Calibrated power output: —10 to —90 dbm
Direct-reading attenuator, accurate to 2%

MICROWAVE POWER SOURCES
18,000 to 50,000 mc

9 interchangeable plug-in tuning units
High power output: 10 mw from 18,000 to 33,520 mc.
Between 9 and 3 mw in higher ranges, depending on frequency.



PLUG-IN INTERCHANGEABILITY

Now you can work at Extremely High Frequencies with one basic microwave generator, using only the tuning units in the ranges you require immediately. Later, as your work expands to other frequencies, **add only tuning units — not complete generators.**

All instruments provide: a direct reading wavemeter, indicating frequency to 0.1% accuracy; continuous tuning over entire range; 1,000 cps internal square-wave modulation — or external modulation; direct waveguide output connectors. All are designed for quick, easy inspection and servicing.

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POLARAD ELECTRONICS CORPORATION

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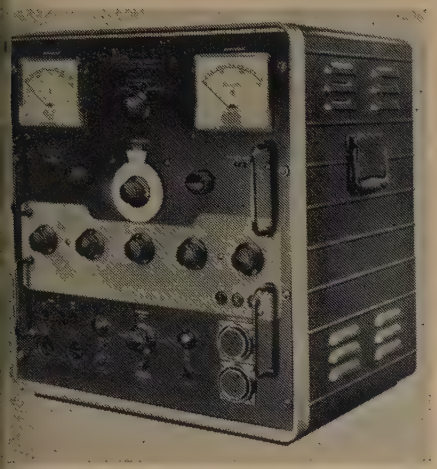
Representatives in principal cities

NEW PRODUCTS

PRD UNIVERSAL KLYSTRON POWER SUPPLY



A recent addition to the "Pacemaker" line of Polytechnic Research & Development Co., Inc., is the Type 812 Universal Klystron Power Supply.

The new Power Supply features digital read-out for beam and reflector voltages; dual outputs for the simultaneous operation of two klystrons; and front panel provision for checking reflector and grid voltage readings. The 812 also provides multi-range beam current overload protection; safety lock on transferring from negative to positive grid voltage; and external triggering of the internal pulse generator.

Consisting of four separately regulated supplies, including beam, reflector, grid and heater, it is designed with internal modulation for pulse, square wave, sawtooth, and sine wave operation. Rise and decay time is only 2 micro-seconds maximum.

Voltage range of the beam supply is 200-3600 volts d.c.; current is 0-125 ma (limited to a load power of 360 watts maximum). The Reflector supply has a voltage range of 0 to —1000 volts d.c. negative; current is 50 microamps maximum for stated output voltage accuracy. The grid supply voltage range is 0-150 volts positive and 0 to 300 volts negative; current is 5 milliamps maximum (positive grid).

The unit is 22-5/32" H x 20-3/16" W x 15-3/4" D, weighs about 180 lbs., and is suitable for rack mounting.

CIRCLE READER SERVICE CARD 101

CASTING RESIN ABSORBER FOR WAVEGUIDE

Emerson & Cuming, Inc., Canton, Massachusetts, has introduced a new product designated Eccosorb CR. It is a casting resin which can be used to mold to size waveguide terminations and attenuators. When cured, it has high attenuation over the full microwave frequency range.

Eccosorb CR is supplied as a two-component liquid system. When properly proportioned and cast, the material can be cured to a rigid plastic which will reproduce mold dimensions accurately. It can then be readily machined, if required. Cure can be accomplished at room temperature or rapidly at elevated temperature. Both step-tapered and uniform-tapered loads can be produced.

The photo shows Eccosorb CR being cast in a mold to produce a flap attenuator. Two finished pieces are in the foreground.

CIRCLE READER SERVICE CARD 102

• • •

ANTENNA CALCULATOR

An improved version of Gabriel's original "Antenna Calculator" has been developed to simplify computations for determining the parabolic antenna parameters of microwave antenna systems.

The calculator scales include frequency, wavelength, beamwidth, gain, return loss, VSWR, windloading, focal length, and other scales relating to parameters for parabolic antennas. A spectrum scale has also been included for band designation and frequency bandwidth.

The calculator may be purchased for $2.00 from Gabriel Electronics Division, The Gabriel Company.

CIRCLE READER SERVICE CARD 103

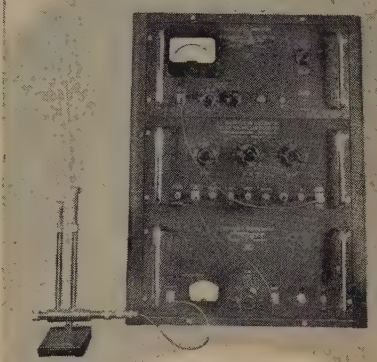
MEASURE ATTENUATION DIRECTLY up to 30 db

WEINSCHEL

single channel INSERTION LOSS TEST SET

Maximum systems error: .1 db
Resolution about .02 db
Frequency Range: 20 MCS to 90,000 MCS

KEY INSTRUMENTS



Bolometer Preamplifier, Model BA-1B
Features wide dynamic linear range, extremely low noise level, cannot burn out barretter.

AF Substitution Attenuator for RF Square Law Detector, Model CF-1
Calibrated directly in rf power ratios; has high input impedance, low output impedance.

Audio Level Indicator, Model IN-1
Precharging circuit reduces required observation time. Has adjustable indicator time constant, low noise level.

Double Stub Tuner, DS-109
For theory, method, required instruments and recommended accessories, request Application Notes #1.

Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12 KMC. Write for complete catalog, specifying frequency range of interest.

WE CO

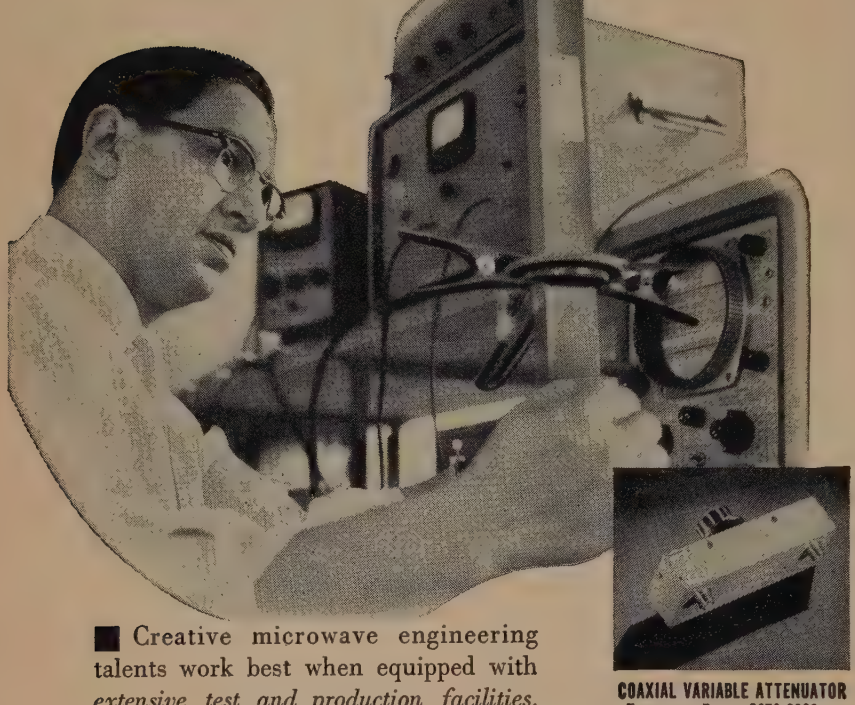
Weinschel Engineering
KENSINGTON, MARYLAND

CIRCLE READER SERVICE CARD 13

In advanced **microwave** *development . . .*

FACILITIES

make the Difference

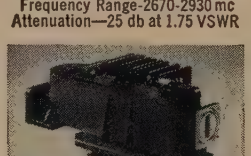


■ Creative microwave engineering talents work best when equipped with *extensive test and production facilities.* Here at PREMIER, our inventive, experienced engineers have at their disposal test and production equipment on a par with the most advanced in the entire microwave industry.

These integrated facilities enable PREMIER to exercise complete control over all steps of production from theory to finished component, thereby assuring complete uniformity . . . and over-all excellence.

Whatever your problem in advanced microwave development, you can expect to find your most efficient . . . and economical . . . solution at PREMIER. Some typical PREMIER products are depicted at the right.

For detailed technical information, write to:



COAXIAL VARIABLE ATTENUATOR
Frequency Range-2670-2930 mc
Attenuation—25 db at 1.75 VSWR

HIGH POWER VARIABLE ATTENUATOR
Power Level—300 kw peak for 8.5-9.6 Kmc
Attenuation—.1-40 db at 1.15 VSWR

WAVEGUIDE SWITCH
VSWR-1.06 maximum
Isolation-100 db minimum

COAXIAL DIRECTIONAL COUPLER
Coupling Values—20 to 50 db
Directivity—greater than 30 db

PRECISION IS PREMIER
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33 New Broad Street, Port Chester, N. Y.

THE WAVEGUIDE HOUSE
CIRCLE READER SERVICE CARD 14

WEINSCHEL 50 OHM COAX. TERMINATIONS NOW AVAILABLE WITH TYPE TNC CONNECTORS

Weinschel Engineering of Kensington, Maryland announces that their Model 535 50-ohm coaxial terminations are now available with type TNC connectors (male or female), in addition to type N, C, SC, and BNC.

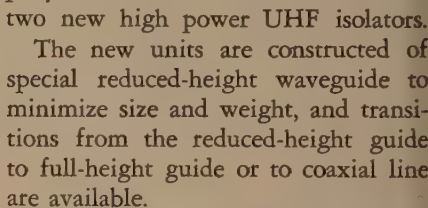
The Model 535 terminations operate in the frequency range D-C to 10 kmc, and will handle 1 watt avg. power and 1 KW peak power. Individual VSWR calibration data is supplied for D-C, 400, 1,000, 2,000, 4,000, 7,500, and 10,000 mc.

CIRCLE READER SERVICE CARD 104

TWO NEW HIGH POWER UHF ISOLATORS FROM RAYTHEON

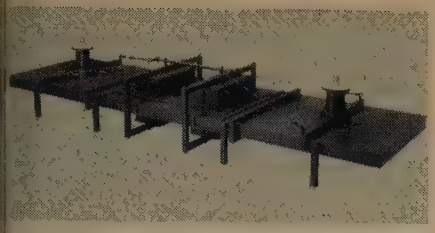
The Raytheon Manufacturing Company announces the introduction of two new high power UHF isolators.

The new units are constructed of special reduced-height waveguide to minimize size and weight, and transitions from the reduced-height guide to full-height guide or to coaxial line are available.



Model IUH1 operates in the range 500-700 mc. It is 6¾″ high, 19″ wide, 30″ long, and weighs 100 lb less transitions. A cooling structure for this model is available for use at the higher power levels. The unit's minimum transmit/receive isolation is 9 db, maximum insertion loss is 1 db, average power handling capacity is 10 KW without cooling, and peak power capability is 10 MW.

Model IUH2 is designed to operate in the frequency range 350 to 400 mc



nd is the result of recent Raytheon udies in the extension of low fre-uency high power isolator operation own to 350 mc. This isolator is 10″ igh, 27″ wide, and 36″ long. With ansitions added, the complete unit is 5″ high, 27″ wide, 90″ long, and eighs 450 lbs. Over the frequency nge, the isolation is greater than db and the insertion loss is 1 db max-num. The device is capable of op-ation at average power levels exceed-ng 10 KW, and has a peak power apacity estimated at 10 MW.

IRCLE READER SERVICE CARD 105

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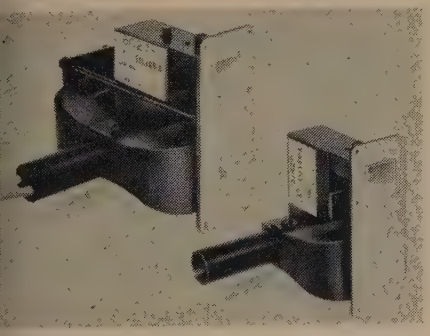
TWO RUGGEDIZED X-BAND MAGNETRONS FROM SYLVANIA

Two ruggedized versions of X-Band nagnetrons have been announced by ylvania Electric Products, Inc.

The new tubes, developed at Syl-ania's Special Tube Operations plant t Williamsport, Pennsylvania, are the ype 2J42B and a ruggedized version f the type 6027H. Both tubes are xed-frequency X-Band devices and enerate minimum peak power out-uts of 14 KW in the case of the J42B, and 18 KW in the case of the 027H.



Having been especially designed for nissile and other airborne applications, oth tubes are capable of withstanding g vibration at 10 to 500 cps with ess than 3 MC frequency shift; and ess than ± 0.5 MC frequency modula-on. In addition, the tubes will with-and a 50 g shock for 4 milliseconds; nd may be operated at altitudes of p to 60,000 ft.

IRCLE READER SERVICE CARD 106

(*More New Products on page 48*)

NOW...a HIGH SENSITIVITY LOW COST SPECTRUM ANALYZER from 10 mc to 44,000 mc with ONE TUNING HEAD

PANORAMIC'S advanced new MODEL **SPA-4**

A new and welcome addition to Panoramic's long line of widely accepted and completely dependable Spectrum Analyzers, the SPA-4 covers frequencies from 10 mc to 44,000 mc in one *low-cost* compact unit that provides better *sensitivity* than found in typical multi-tuning head spectrum analyzers.

Backed by Panoramic's forward thinking, long and specialized experience in the development of spectrum analyzers, the SPA-4 embodies the human engineering and stable, direct reading displays that facilitate rapid and reliable analyses of measurement problems.

The SPA-4's many unique features, tremendous flexibility and single operation make it unsurpassed for analysis of FM, AM and pulsed systems, instabilities of oscillators, noise spectra, detection of parasitics, studies of harmonic outputs, radar systems and other signal sources.

- Better sensitivity than with typical multi-tuning head spectrum analyzers
- Resolution continuously variable from 1 kc to 80 kc for analysis of wide and narrow pulsed RF signals
- 70 MC wide sweep width continuously adjustable down to 0 mc
- Careful shielding to avoid interference
- Calibrated power, voltage and log amplitude scales
- Constructed to MIL specifications

Write, wire, phone NOW for detailed specification bulletin.

Panoramic instruments are Proved Performers in laboratories, plants and military installations. Find out how a Panoramic instrument can help you. Send for our *new* catalog Digest and ask to be put on our regular mailing list for The Panoramic Analyzer featuring application data.

dependable CERTIFIED SPECIFICATIONS *for accurate data*

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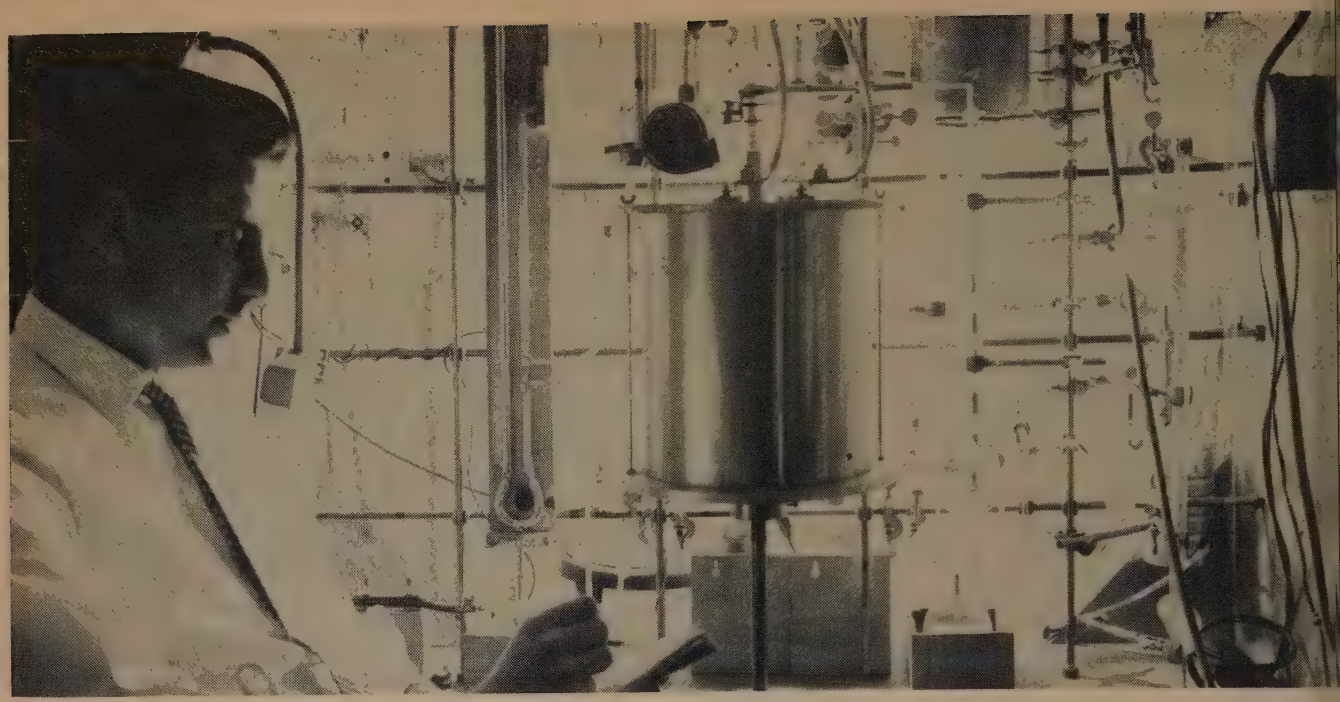
CIRCLE READER SERVICE CARD 15



Research division photo shows high temperature studies of magnetic oxides which provide data for development of ferrites with improved magnetic and electrical properties.

Company Profile:

RAYTHEON

Part II

Last month we traced the rise of Raytheon from a small receiving-tube producer to a major electronics firm of twelve divisions. This month we give a run-down of the Raytheon divisions mainly devoted to the microwave art.

Government Equipment Division

This division of 9520 employees, headed by Homer R. Oldfield, Jr. designs, manufactures, and tests electronic equipment and systems for both military and civilian departments of the Government. Microwave radar applications predominate.

Typical projects include Arctic DEW line radars, air traffic control radars for the F.A.A., storm detection radars for the Weather Bureau, navigation and bombing radars for Air Force intercontinental bombers, and Doppler and search radars for the supersonic B-58 Hustler.

Other microwave projects include countermeasures equipment for the Air Force and portable communications equipment for the Marine Corps.

Main design center for radar and other military equipment except missiles is the Wayland (Mass.) Laboratory, completed in 1955. With recent additions, it provides eight acres of laboratories, drafting rooms, offices, and machine shops.

The Maynard (Mass.) Laboratory specializes in CW radar techniques. Typical projects are Doppler navigator and airborne intercept radars, altimeters, miss-distance indicators, and countermeasures equipment.

The Santa Barbara Laboratory, located near the heart of the West Coast electronics and aircraft industries, is concerned with passive countermeasures techniques, infrared and optical guidance and mapping techniques, and the design and development of radar antennas, modulators, and pulse generators. Test facilities include a 400-foo folded-path infrared test range.

The division's production plants are located in Waltham and North Dighton, Mass.

Missile Systems Division

This activity, founded in 1944 as a small group assigned to develop an active target seeker and flight-control assembly, is now Raytheon's largest division. There are more than 13,500 employees, headed by David D. Coffin.

In 1950, a Raytheon guidance system enabled the Navy's experimental Lark to achieve the first successful interception and destruction of an aircraft in flight by a guided missile. Today, Raytheon is the only electronics company holding prime contracts for two major missiles — the Army's ground-to-air Hawk and the Navy's air-to-air Sparrow III.

According to the military, these missiles possess unique defense capabilities against certain types of potential air attack. Guided by new-type radars, they track and destroy aircraft flying at even the lowest altitudes in the blind zone of conventional targets.

The Sparrow III is already operational with the Fleet as the primary armament of carrier-based F3H-2 jet interceptors. Since it permits a relatively wide margin of aiming error, it can be employed effectively by maneuvering aircraft.

The Hawk, intended both for continental defense and for field service with Army and Marine combat forces, were

to production early in 1958 at the Andover, Mass. plant. ne NATO countries of Europe also are planning to opt the Hawk.

Raytheon's missile development center is the Bedford Mass.) Laboratory, completed in 1954. Work is now derway at Bedford on the problems of detecting and acking IRBM's and ICBM's.

The division maintains flight-test facilities at Hanscom ir Force Base, as well as field test laboratories at Oxnard, lif. (adjacent to the Navy's Air Missile Test Center at oint Mugu) and at White Sands, N.M. (within the rmy's Missile Range).

Division headquarters are located in the Waltham Instrial Park, Route 128. Production plants are in Lowell d Andover, Mass. and Bristol, Tenn.

icrowave and Power Tube Division

It was the combined success of this division and that the old Equipment Division which launched Raytheon its course of microwave pioneering. The Microwave and wer Tube Division was created in 1942 to develop and oduce magnetrons for the war effort. Today, Dr. Percy Spencer, its founder, heads a group of some 3500 emoyees who have been responsible for the design of more an 600 different tubes, the majority being microwave pes. Available as unclassified stock items are 83 types magnetrons and 50 types of reflex klystrons. Raytheon is e largest producer of microwave tubes in the world.

The division also produces backward-wave devices and aveling-wave tubes, as well as storage tubes which conbute to microwave systems.

A special Raytheon achievement is the Platinotron, a w basic type of microwave tube related to the magnetron, nich can be applied either as an ultra-stable microwave cillator called the Stabilotron, or as a microwave amplifier lled the Amplitron. By overcoming the power limitaons of the magnetron, the Amplitron greatly extends the pability of long-range radar and promises to open up tirely new applications for microwave energy.

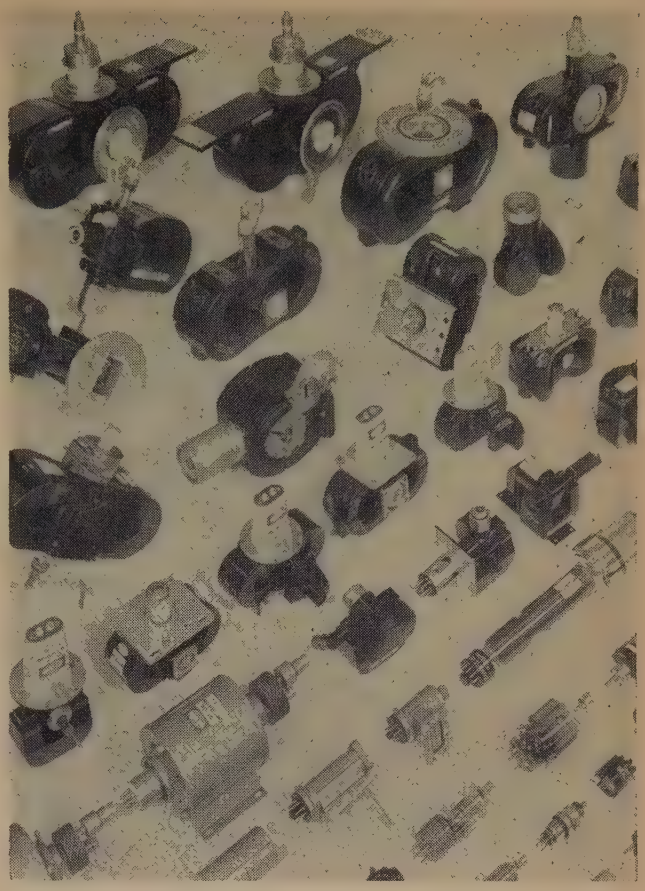
Applications for Raytheon microwave tubes include ound, airborne, big-ship, and small-craft radars; weather recasting, traffic control, and harbor surveillance radars; icrowave communications links; miniature beacons; mise control systems; electronic ovens; and microwave diaermy units.

Division headquarters as well as principal laboratory d plant facilities are centered in Waltham, with addinal plant facilities in Newton Highlands. Just comeeted in Burlington, Mass., is a new laboratory named honor of Percy Spencer, which provides 150,000 square et of additional floor space for tube development and sign.

quipment and Systems Division

One of two new activities formed by a recent splitting the old Commercial Equipment Division (which emoyed about 2000 people), this new division, headed by hn H. Beedle, will concentrate on complete equipment d systems ready for end users. Products will be elecnic, electrical, or electromechanical in nature, and of commercial type.

Present microwave product lines include Mariners Pathder radars and microwave relay links for television broadsting and rural communications. Latest addition to the dar line is a river navigation model with a slotted waveide antenna and improved receiver circuitry which pro-



Array of microwave tubes produced by Raytheon's Microwave and Power Tube division.

vide extra-sharp images and an extremely short minimum range.

Advanced military features such as ferrite isolators and duplexers are being incorporated in the commercial line. Accessory units to provide true-motion PPI presentation are already available.

Under development is an ultra-compact radar for pleasure craft and small fishing craft. Also under development are harbor surveillance radars which can be combined with microwave relay systems for remote traffic control.

Microwave TV relays are undergoing continuous development to meet the stringent demands of color telecasting; special models are being designed to handle CBS field-sequential color signals for closed-circuit TV. Just announced is a new multi-channel microwave relay for industrial, common-carrier and Government Services.

Industrial Apparatus Division

Headed by J. Penn Rutherfoord, the second new division resulting from the split of the old Commercial Equipment Division will concentrate on "building block" components and apparatus to be used by other manufacturers as integral parts of their products or as production apparatus.

Microwave product lines include "Radarange" electronic ovens for the food service industry as well as components for domestic electronic ovens produced by other manufacturers. Under development are prototypes for new domestic ovens that can be produced and marketed at more competitive prices with no sacrifice in performance.

A line of laboratory generators has been introduced for use in free-radical research and spectroscopy. Other in-

dustrial applications for microwave power generators are under investigation.

Research Division

While several company divisions conduct research programs for application to their own products, the company also maintains a research center in Waltham headed by Dr. T. H. Johnson which serves the immediate needs of all divisions as well as conducting long-range investigations to ensure the company's future. The division employs about 350 people.

Primary fields of effort, both theoretical and experimental, are solid-state physics, semiconductors, microwave tubes and devices, and plastics.

Other achievements include a detailed explanation of the behavior of polycrystalline ferrite materials at microwave frequencies; and the Spacistor, a new semiconductor concept now under development which combines several advantages of transistors and vacuum tubes, and which employs a high electrified space-charge region for amplification in the microwave region.

Research Division scientists have materially assisted other divisions with special problems of microwave circuitry; the interaction of microwave energy with various materials; and noise generation in microwave tubes for advanced military applications. Masers and parametric amplifiers of several types are among the newer microwave devices under investigation.

Recently completed was a program conducted by a food technologist over several years to determine the characteristics of microwave heating as applied to the cooking of food and to determine optimum techniques for the use of microwave ovens.

The Research Division maintains close working relationships with MIT, Harvard, and other leading universities in order to maintain a continuing flow of scientific information and to attract able scientists.

Special Microwave Device Group

This new product group in Waltham, which originated in the Research Division and is still a part of it, runs the whole gamut from applied research to marketing in the field of ferrite materials and devices. Established in 1957 by Dr. Howard Scharfman, the present manager, the Special Microwave Device Group is organized into three departments employing a total of 55 people.

The research and development department is active in every phase of the microwave ferrite art; it specializes in the development and production of ferrite and garnet materials as well as in the pilot production of ferrite devices. The production department is equipped to handle large and small production runs of custom devices and catalogue items. The sales department carries on the group's advertising and marketing activities while benefiting from the resources of a major electronics organization.

Major contributions have been made by the group in the development of the first high-power, UHF and L-band isolators and S-band circulators. Recent developments include a high-power 350-400-mc isolator, a new type of amplitude modulator covering all of X-band, and a series of small, light "Y" circulators at L, S, and X-bands particularly suited for maser and parametric amplifier applications. In addition, the group has a full line of conventional isolators from the UHF band through K-band designed for low, medium, and high-power application; of particular interest is the line of miniature low-pow isolators from C through K-band.

Future activities will be tuned to specific custom requirements, as well as to breaking new ground in more esoteric and as yet almost untouched fields of lim ers, mixers, filters, sideband generators, switches, a modulators.

Subcontracting

Raytheon's roster of vendors and subcontractors inclu more than 4000 firms from coast to coast. Approximat 80 percent of these are small businesses, many of th highly specialized, with unique skills and reputations fine craftsmanship. Raytheon has repeatedly stated t without the good will and cooperation of its colleagues small business, the company's military production achie ments would have been impossible.

Small-business procurement at Raytheon may be ill trated by considering a typical major project, the AN/T 1D radar. This is a high-power transportable air-sea equipment for the early detection of enemy aircraft a other objects. It was designed for ground-base operati either in the field or at a fixed position.

The AN/TPS-1D was manufactured for the Navy un 6 contracts totaling more than 1,000 sets. It was used n only by the Navy but by the Signal Corps, Marine Cor and Air Force, and was furnished under the Mutual Defe Assistance Program to some of the member nations NATO and SEATO. Production was continuous fr 1951 to 1956.

The total sales value of the AN/TPS-1D was more th $48,000,000. Total purchases from vendors amounted $27,859,555, or 57.8 percent of the total sales value, which $16,269,980, or 54.4 percent, was placed with sm business, with the remaining 41.6 percent being award to large business. Furthermore, a portion of the la business share was further subcontracted, with the res that approximately 12 percent of additional purchases, $1,390,749, eventually found its way to small business.

The large preponderance of New England vendors flects not only the company's policy of doing business w local suppliers where possible but also the special ski characteristic of that area.

Procurement for a highly complex equipment such the AN/TPS-1D is far more than a routine matter writing purchase orders and specifications — it frequen involves continuing technical liaison with vendors, ev to the extent of setting up production and quality-cont procedures and training vendors' personnel.

Furthermore, it is Raytheon's policy to incorporate t latest knowledge both from the engineering laborator and from the field into the production line during t performance of the contracts. As a result, more th 2,000 engineering change orders were issued, many which called for changes in vendors' production procedu and consequent reeducation of workers.

In view of this need for maintaining personal sup vision of vendors' operations, it is noteworthy that sections of the country benefited to some extent fr the AN/TPS-1D contracts.

AN/TPS-1D production was considered so vital duri the Korean conflict that Raytheon was asked to establi a second source of manufacture. Accordingly, subcontra for the production of complete AN/TPS-1D units, su as the indicator unit, were awarded to several small bu nesses experienced in the manufacture of high-grade el

ronic equipment. In order to bring these manufacturers o the point of delivering their first units, an immense mount of liaison was required. Some 15,000 drawings vere forwarded; a total of 52 man-weeks were spent by he vendors' personnel at the company; and 140 man-veeks were spent by our personnel at the vendors' plants.

Government Services Division

One of the factors in building Raytheon's equipment eputation has been the engineering follow-through pro-ided by the Government Services Division, headed by). L. Dewey. The history of this active group actually oes back to the early days of operational radar — the ucleus of Field Engineers who provided installation and nstructional services on the U.S. Navy's first surface-earch systems, has grown into an organization of some 50 people with representatives at ninety locations in the J.S. and in eighteen foreign countries. These men close he information loop by extending equipment know-how o maintenance personnel, and by feeding back the per-ormance data so necessary for product improvement.

When the AN/TRC-27 microwave communications quipment was recently developed for use by the Marine Corps, Government Services played a major role. Key naintenance and instructor personnel from the using units eceived indoctrination in microwave techniques at the Waltham plant prior to equipment delivery. Field Engi-neers who had assisted in evaluation of the prototype were n hand when equipment was introduced to the field. Their eports on its performance in the ultimate environment re now providing valuable data that relates to future esign.

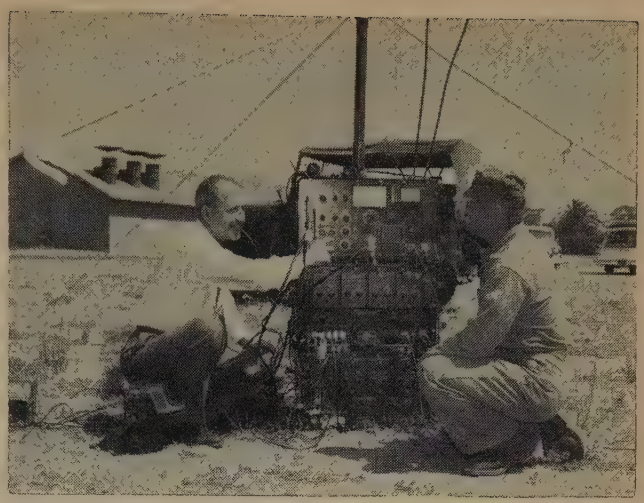
The Government Services Division is expanding its ctivities and entering into new working relationships with nilitary and Government-end-use customers. These in-lude "package" installation programs for the more elab-rate communications — electronic facilities, specialized eld engineering studies, and complete overhaul and epair of electronic systems at the division's field service acilities. The division presently provides support on air-raffic control, doppler-navigation, surface-search, fire-con-rol, and early-warning radar; microwave communications quipment; sonar; missile systems; electronic counter-neasures; and infrared developments.

nternational Division

With growing emphasis on world trade, the activities f the International Division have increased considerably n the past few years. The division of about 65 people eaded by Ray C. Ellis is currently represented throughout he world by 83 carefully selected distributing firms. hese firms are qualified to promote the sale of Raytheon roducts and to maintain the necessary facilities for servic-ng them. In addition, Raytheon maintains its own service acilities for radar and marine products in 167 foreign orts.

The company also has licensing agreements with 16 nanufacturers in nine foreign countries. These agreements rant them the right to manufacture selected equipment on royalty basis under Raytheon's patents or technical super-ision.

A two-way exchange of technical ingenuity and engi-eering development exists between Raytheon and its icensees. Many Raytheon licensees are pioneers in their elds, and are leading electronic manufacturers. Micro-mbda of Italy contributed to the development of the



Prior to delivery of the AN/TRC-27, key U.S.M.C. personnel were instructed in microwave techniques by Raytheon field engineers.

cosecant-squared antenna for the AN/TPS-1D radar system, and has been responsible for a new shipborne air-search radar. Sindel and Elsi, also of Italy, have both contributed materially to systems as well as component development. Atlas-Werke of Germany, Raytheon's oldest licensee, is one of the largest marine suppliers in Europe, and an important manufacturer of advanced electro-medical equipment. The Oki Electric Industry Company of Japan was manufacturing telephone equipment five years after its invention by Alexander Graham Bell in 1876. Today, it produces Raytheon's radar and marine electronic equipment for the Far Eastern market.

Foreign subsidiaries are now operating in Canada, Latin America and Europe, and a further increase in their number is anticipated. In Europe alone, Raytheon expects to increase its business eight-fold within the next six or seven years.

Looking Ahead

As everyone knows, Raytheon is continually in the news. New plants, major military contracts, and ever-increasing employment — all show that the company is growing like asparagus in May. Since the first part of this profile went to press, employment has passed the 39,000 mark, sales of $375 million have been announced for 1958, and sales of $400 million are assured for 1959 if current volume is merely maintained without further increase. How far will this spectacular growth continue?

Management sees no possibility that military demands will be relaxed in the foreseeable future but rather that they will increase. As for the commercial market, the new divisional structure reflects a determined effort to increase the company's strength in this area, both by the internal development of new products and by the acquisition of outside companies that have proved their success in related lines. It is likely that most of the new military products and many of the commercial ones will be in the microwave field.

Raytheon intends to hold its growth well within the limits of its logical destiny as determined by proven ability to meet essential needs of Government and industry. Speaking in this context, Harold Geneen, executive vice president, says, "There is nothing in the picture to suggest we'll be doing less than one-half billion dollars in business in the next three or four years."

1959 PGMTT National Symposium Committee (left to right): P. Crandell, National Co.; P. Rizzi, Ewen Knight; W. From, Financ Ewen Knight; I. Goldstein, Raytheon; K. Willenbrock, Harvard University; H. Riblet, Technical Program, Microwave Develo ment Labs.; W. Pritchard, Symposium Committee Chairman, Raytheon; R. Rivers, Publicity, Aircom; Mrs. W. Pritchard, Lad Program; Mrs. T. Saad; T. Saad, Local Arrangements, Sage Labs.

PGMTT NATIONAL SYMPOSIUM FOR 1959

The 1959 PGMTT National Symposium sponsored by the IRE Professional Group on Microwave Theory and Techniques, in cooperation with the Division of Applied Physics, Harvard University, will be held at Paine Hall, Harvard University, Cambridge, Mass., June 1-3, 1959.

The Technical Program Committee chairman is Henry Riblet. Other members of this committee are Carl Faflick, Irving Goldstein, Victor Jones, John Reed, Peter Rizzi and Karl Willenbrock.

Advance registration is urged. Free parking stickers are reserved for the advanced registrants. Registration fees are $3.00 for IRE members, $5.00 for non-members, students, free. The banquet is $6.00 and luncheons are 95 cents per person. Parking stickers for late registrants are $1.00 if any are left. Send advance registration to William From, Ewen Knight Corp., 206 A Street, Needham, Mass. Make checks payable to W. H. From, Treasurer.

A ladies' program will include a tour of historic Boston on June 1, a tea and tour of the Boston Art Museum on June 2, and a luncheon on Wednesday June 3.

The banquet program is as follows:

Place: Harkness Commons, Harvard University, Cambridge, Mass.

Time: Cocktail hour: 6-7 P.M., June 2, 1959.

Toastmaster: W. L. Pritchard, Symposium Committee Chairman.

Opening remarks: Professor Harvey Brooks, Harvard University.

Microwave Prize: Awarded by T. S. Saad, Chairman PGMTT Administrative Committee.

Banquet Address: Professor E. M. Purcell, Harvard University.

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CASE INSTITUTE ANNOUNCES SHORT COURSE ON MICROWAVE THEORY

A summer study course, designed to meet the demands presented by widespread use of radar and the increased use of microwave heating, testing and communication systems in industry, will be offered from July 20-31 by Case Institute of Technology.

Directed toward the engineer in industry and government who has found a growing need for training in the methods of microwave engineering, the short course in microwave theory will be headed by Dr. Beaumont Davison, Assistant Professor of Electrical Engineering. The series of lectures and laboratory sessions will be conducted on the beginning graduate level.

Background requirements for engineers wishing to take the course should include college level studies in AC circuits and elementary electron tube circuits, as well as mathematics through differential equatio

Dr. Davison points out that man engineers are finding their bac grounds inadequate for handling th problems brought about by comple microwave systems. The Case sum mer course is designed to cover th fundamentals of generation an transmission at high frequency an in addition, embraces some of th new industrial applications of micr wave radiation.

Additional information on the m crowave course can be obtained fro Dr. James R. Hooper, Jr., Directo of Special Programs, Case Institut of Technology, Cleveland 6, Ohio.

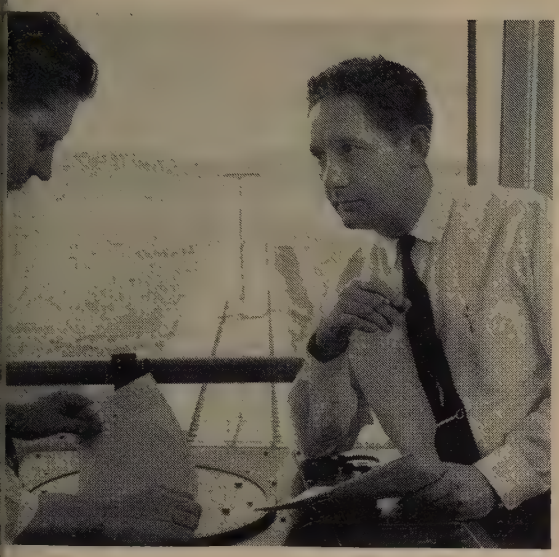
• ● •

Paul Hines, president of New En land Instrument Company, manufa turers of conductive plastic and pr cision wire-wound potentiomete announced the signing of a lon term lease for additional new facil ties on Route 128 in Waltham, Ma sachusetts. This building will hou the company's engineering and sal departments. New England Instr ment will continue to maintain the other engineering and manufactu ing facilities in Waltham, Mass., an in Woonsocket, Rhode Island.

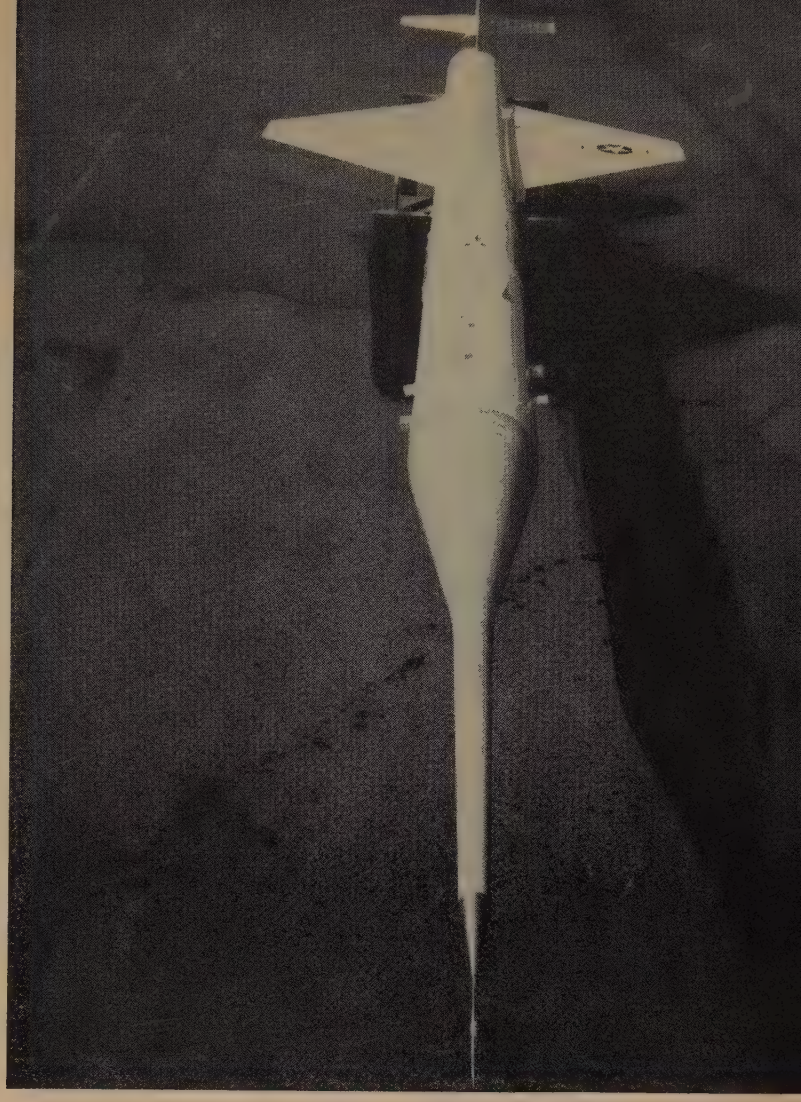
This latest addition brings tot space to 15,000 square feet. The e pansion was prompted by the rap growth and acceptance of the co pany's new lines of conductive plas and precision wire-wound poten ometers.

(right) Lockheed Q-5 target missile features telemetry that registers miss-distance and theoretical hits in testing accuracy of other missiles.

ANTENNA—TELEMETRY



Studying results of antenna pattern measurements — part of the activity of the Space Communications laboratory.



Expanding the Frontiers of Space Technology

Lockheed maintains extensive research capabilities for the development of antennas and telemetering systems and spacecraft applications.

Laboratory studies in antennas and electromagnetic propagation include the application of solid state materials to microwave transmissio line components; the design of antennas to survive the rigors of space flight; the effects of space on radio signals and radar detection; and the scattering from missile shapes and space vehicles. Research is also being conducted in the application of ferrites and MASERS; on problems of radio transmission between space vehicles and Earth, re-entry scattering and diffraction by man-made objects and ionized gases; and development of antennas for data link systems between satellites and ground stations.

Telemetering has been brought to a high degree of successful applicatio in the integration of circuits and components into high-performance systems. A completely sub-miniaturized FM-AM system has been developed, along with a complete PAM-FM system characterized by highly efficient band-width utilization, low power consumption and economy of size and weight. This represents a significant achievement in the field of high capacity telemetry.

Scientists and engineers of outstanding talent and inquiring mind are invited to join us in the nation's most interesting and challenging basic research and development programs. Write: Research and Developmen Staff, Dept. D-27, 962 W. El Camino Real, Sunnyvale, California.

"The organization that contributed most in the past year to the advancement of the art of missiles and astronautics."

Lockheed

MISSILES AND SPACE DIVISION

SUNNYVALE, PALO ALTO, VAN NUYS,
SANTA CRUZ, SANTA MARIA, CALIFORNIA
APE CANAVERAL, FLORIDA · ALAMOGORDO, NEW MEXICO

Microwave Engineers

Join long-range, advanced development programs to create new microwave devices

In the Microwave Development Laboratories of the Radio Corporation of America, at Princeton, N. J., and Lancaster, Pa., engineers are engaged in long-range programs on a variety of microwave devices (super power klystrons, grid controlled amplifiers and switch tubes, conventional power level microwave devices, traveling wave tubes, parametric amplifiers and microwave solid state devices, high-speed switches and high perveance electron guns).

In essence, the challenge in the advanced development laboratories is to achieve further advances in these areas of significant scientific importance.

Opportunities are available offering unlimited progress to engineers with PhD and MS degrees (Physics and EE) who can contribute new concepts in these fields or can lead engineering groups investigating new microwave devices and utilizing new operating principles.

INVESTIGATE THESE OPPORTUNITIES — SEND RESUME IN COMPLETE CONFIDENCE:

FOR PRINCETON, N. J.

Mr. J. F. McPartland
Professional Personnel
Dept. J-3D
Radio Corporation of America
Electron Tube Division
Harrison, N. J.

FOR LANCASTER, PA.

Mr. E. F. Stevens, Mgr., Employment
Dept. G-15D
Radio Corporation of America
Electron Tube Division
New Holland Pike, Lancaster, Pa.

EQUAL JOB OPPORTUNITY For All Qualified Applicants

RCA

RADIO CORPORATION of AMERICA
ELECTRON TUBE DIVISION

NEW PRODUCTS

NEW COAXIAL TERMINATION

The Radar Design Corporation of Syracuse, New York announces the development of a small, light, and extremely wide range coaxial termination.

The new termination, designated as Model RDL-3N-Special-2, is approximately one inch long, weighs only two ounces, and has a VSWR of less than 1.05 from D-C to 10 kmc. Available with Type N male or female connector, the unit has a power rating of 1 KW peak.

Additional information on the new termination together with a copy of RDC's new and recently published catalog is available on request.

CIRCLE READER SERVICE CARD 10

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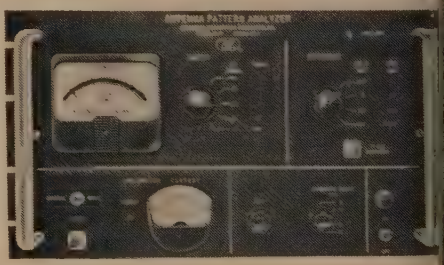

ANTENNA PATTERN ANALYZER BY WEINSCHEL

An Antenna Pattern Analyzer, Model BA-7, is announced by Weinschel Engineering of Kensington, Maryland. This new instrument is designed to utilize both RF crystals and barretters in its video detector system.

When using crystals, the instrument requires just 1 microwatt of RF power to achieve a maximum range of measurement of 45 db in one step.

CIRCLE READER SERVICE CARD 10

DuMONT ENTERS MICROWAVE FIELD

With its development and production facilities completed the Allen B. Du Mont Laboratories, Inc., Clifton, New Jersey, have entered the microwave field as a major source for planar triodes and related microwave tubes. An initial production run is underway for the company's first microwave tube, the Du Mont Type 6280 Planar Triode.

The tube operates in the frequency range 4,000 to 5,000 MC, and except for its much tighter tolerances, is a direct replacement for the Type 416B Planar Triode—a tube already on the market. The acorn-sized tube is gold plated for high-Q operation and has a gain of 9 db min. at 50 mw output when operating at 4,000 MC.

CIRCLE READER SERVICE CARD 109

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MANAGEMENT ENGINEERING BOOKLET

General Transistor Corp., Jamaica, L.Y., is offering a free fifty-page booklet entitled "The Unwritten Laws of Engineering" by W. J. King, published by the American Society of Mechanical Engineers.

This publication is extremely valuable to engineers who are interested in learning good management practice and is helpful to technical administrators as a refresher in the techniques of sound management.

CIRCLE READER SERVICE CARD 110

NEW PLANT

This is the new John Gombos Co. plant . . . designed specifically to meet your requirements for MICROWAVE ASSEMBLIES and other high precision mechanical and electro-mechanical units. If you demand quality and reliability, the John Gombos Co. will meet your needs. We have successfully served the leaders of industry since 1940.

JOHN GOMBOS

COMPANY, INC.

Webro Road, Clifton, New Jersey

CIRCLE READER SERVICE CARD 18

ENGINEERS AND PHYSICISTS R & D ON NEW MICROWAVE DEVICES

Microwave Associates, Inc. invites qualified engineers and physicists to discuss an unusual opportunity to perform R & D work on new microwave devices utilizing ionized media, ferrites and semiconductors. A broad background can be achieved in the interaction of electromagnetic energy with non-linear lossy dielectrics. Here is an opportunity to grasp the advantages of each medium, combine their properties, and develop new devices.

Excellent high power and low power facilities are available for complete study and test of these devices over a wide frequency spectrum — 400 to 70,000 MC.

You are invited to a confidential exploratory discussion of your future with us. Contact Dr. Lawrence Gould for suitable arrangements.

MICROWAVE ASSOCIATES, INC.

BURLINGTON
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GENERAL CERAMICS CORP. OFFERS TWO NEW MICROWAVE FERRITES

General Ceramics Corporation, of Keasbey, N.J., announces two new microwave ferrites, known as R-5 and R-6, which brings its microwave line to four materials of varying saturation magnetization, each of which comes in four different sizes and shapes. All are standard items which can be delivered in development quantities overnight, according to John P. Manley, vice president and manager of marketing.

In addition to supplying microwave materials, General Ceramics grinds them to customers' specifications.

In 1952, General Ceramics became the first manufacturer to offer a microwave ferrite commercially. This was its Ferramic R-1.

Ferramics R-1 and R-4 are Manganese-Magnesium ferrites, while R-5 and R-6 are Manganese-Magnesium-Aluminum.

Data on typical applications, hysteresis loops, magnetic and dielectric properties with relation to frequency, dimensions, and other characteristics of the materials is available in a new engineering bulletin entitled, "General Ceramics Microwave Ferrites." The booklet is free on request from the company.

CIRCLE READER SERVICE CARD 111

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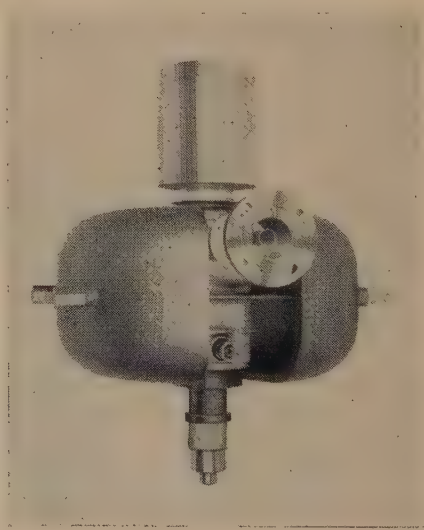
THE VA-802 AMPLIFIER KLYSTRON



Varian Associates' newly developed VA-802 amplifier klystron is a 1 KW cw, air-cooled, 4-cavity tube. The tube can be continuously tuned from 1700 to 2400 MC and is focused with a permanent magnet. Designed specifically for application in forward scatter communication systems, the VA-802 is suitable for both fixed-station and transportable service.

The tube's design and fabrication is aimed at providing simple, trouble-free operation and minimum maintenance.

The general performance characteristics of the VA-802 are as follows:

Frequency Range:	1700 to 2400 MC
Power Gain:	40 to 50 db
Power Output into flat line (VSWR of 1.1 or less):	1000 watts
RF Drive power — for max. efficiency tuning:	0.1 watt max.
Efficiency (typical):	40%
Operating bandwidth	
sync tuned:	4 MC
Stagger tuned:	6-8 MC
Beam voltage:	6 KV
Beam current:	500 ma
Max. dimensions:	18" x 12" x 5"

The tube's RF input terminal is type N coax. and its RF output terminal is 1-5/8" 50-ohm coax.

CIRCLE READER SERVICE CARD 11

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KEARFOTT OFFERS NEW X-BAND FERRITE PHASE MODULATOR

A new X-Band ferrite phase modulator of exceptionally small size and weight has recently been announced by the Microwave Division of the Kearfott Company, Inc., Van Nuys, California.

The new Model W-183-1E Phase Modulator may be used as a frequency translator, side band generator, or as an electronically controlled phase shifter. Boasting a small volumetric enclosure and small insertion length (6" x 1-5/8"), the new unit weighs less than one pound.

Specific characteristics are as follows:

Frequency Range:	9.75 to 10.75 KMC
Insertion Loss:	0.5 db nominal
Phase Shift:	360° minimum
VSWR:	1.10 (typical)
Peak Power:	5 KW
Average Power:	10 watts

Typical control power for 360° modulation at 10 KMC is less than 1 watts, and amplitude modulation is less than 0.3 db variation with control current.

CIRCLE READER SERVICE CARD 11

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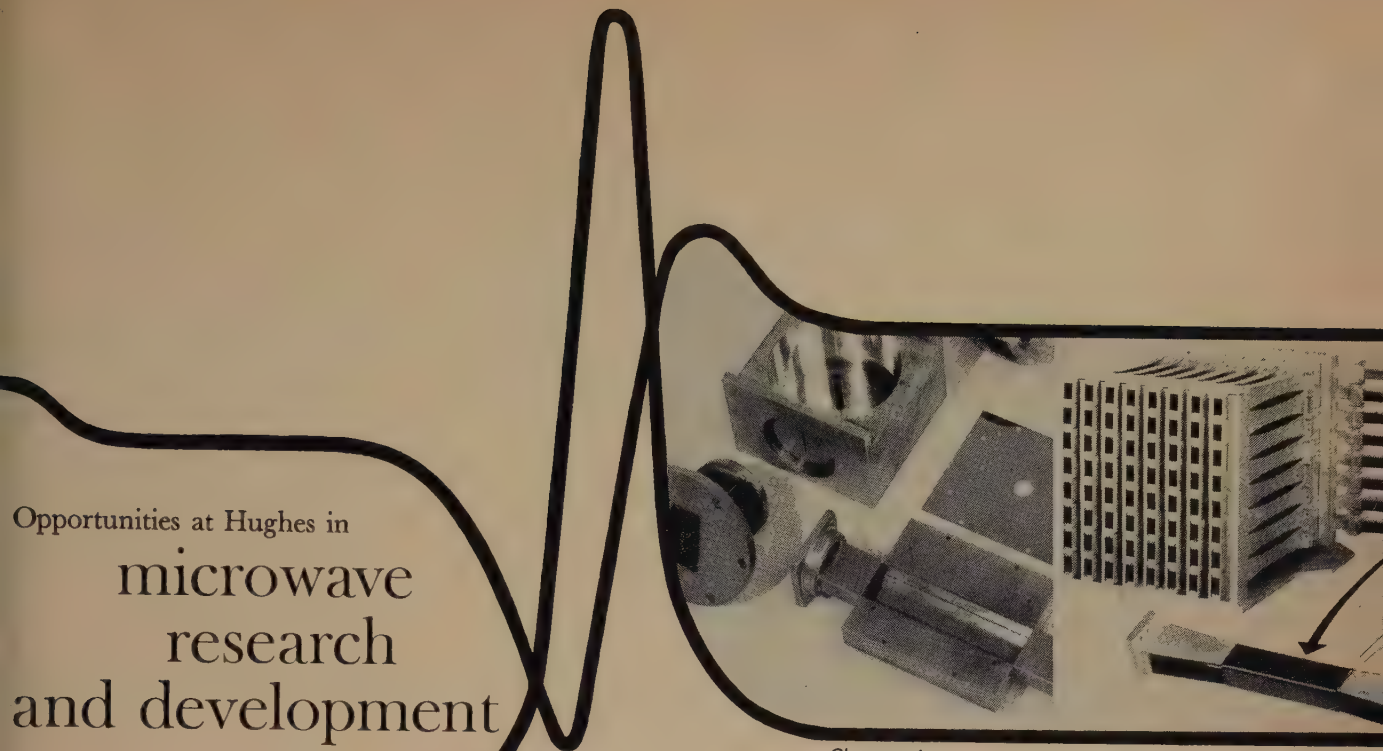
NEW ITEK MULTI-PULSE GATING UNIT

A new Multi-Pulse Gating Unit, Model MPG-2, for use with Itek Microwave Spectrum Analyzers is announced by Itek Corporation, Waltham, Massachusetts. The Gating

(*Please turn to page 52*)

Opportunities at Hughes in

microwave research and development



Close-up of Hughes Ferrite Amplifier

X-Band Reciprocal Ferrite Phase-Shifter Experimental Electronic Scanner

Modern electronic systems demand a broad range of technical competence. The Hughes Microwave Laboratory has unusually extensive capabilities in the antenna, microwave component, and radome fields. Its activities are co-ordinated in a balanced program of fundamental research, development, design and production engineering.

ANTENNA RESEARCH—Included in current studies are: electronic scanning, its information transfer functions, and its relationship to system performance; surface waves and conformal surface antennas potentially useful on nose cones or low silhouette applications; and the theoretical aspects of transmission through small radomes.

ELECTRONICS RESEARCH—These investigations are concerned with basic phenomena such as amplification, harmonic generation, limiting and switching with ferromagnetic and dielectric materials, and superconduction in thin films at microwave frequencies.

MATERIALS RESEARCH—In the field of Solid State Chemistry and Physics, studies are directed toward the synthesis and characterization of organic and inorganic compounds; new polymer systems; structural and electronic ceramics; and ferroelectric, ferrimagnetic and paramagnetic materials for electronic applications.

MICROWAVE ENGINEERING—the products of research are converted into advanced components, processes, and techniques for ultimate system application. Novel antennas, radomes, filters, and ferrite devices are being developed for the entire microwave and UHF spectra. New materials and processes are exploited for the production of ferrites and garnets, silicone plastics, ablative materials, high-temperature insulating and encapsulating materials, and electroluminescent panels. Research and engineering ideas are rapidly embodied in concrete forms through the facilities provided by a versatile design staff and a well-equipped shop.

Openings exist in each of the above areas. These positions offer excellent opportunities for qualified personnel in the fields of Physics, Chemistry and Engineering (Electrical—Microwave—Mechanical).

Please write: Mr. R. A. Martin, Supervisor, Scientific Employment
HUGHES RESEARCH AND DEVELOPMENT LABORATORIES
R and D Personnel Department, Culver City 19, California

the West's leader in advanced electronics

HUGHES

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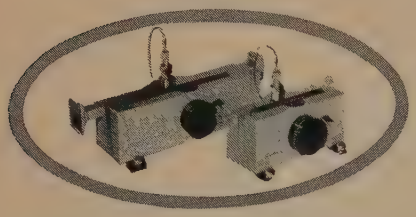
STANDING WAVE DETECTORS

—exceptionally accurate



You get the accuracy that results from perfect parallelism between slot and waveguide axis... between probe travel and waveguide axis. Only 30 seconds needed to equip a D-B slotted line to measure adjacent frequency bands. Range: 5.8 KMC to 140 KMC—covered by a *minimum* of units, to stretch your budget. Literature on request.

DE MORNAY BONARDI

DE MORNAY–BONARDI

780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

CIRCLE READER SERVICE CARD 19

New Products (Continued)

Unit provides the means for analyzing an individual pulse in RF multipulse trains used in complex missile guidance radar systems. Gating circuitry follows the microwave RF head, gating the signal to the I.F. amplifier. Power requirements are 115 volts ±10%, 50-400 cycles, 50 watts. Designed to fit the standard 19 inch rack mount, the MPG-2 can also be used with regular bench top models by the addition of special equipment side panels which are available from the manufacturer. Complete technical information is available on request.

CIRCLE READER SERVICE CARD 114

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FERRITE ISOLATORS FROM PRD

A new line of Ferrite Isolators designed to optimize the output from microwave generators by completely isolating them from reflected load signals, is announced by Polytechnic Research & Development Co., Inc., Brooklyn, New York.

Covering the frequency range from 3.95 to 12.4 KMC in three broadband models, these additions to the PRD Pacemaker line have an insertion loss of only 1.0 db and a VSWR of only 1.2. Each covers an entire waveguide band.

Conservatively rated at 5 watts, these isolators can actually handle up to 25-watts with only a temporary electrical degradation. Model 1205 covers the entire 2″ x 1″ waveguide range with a minimum isolation of 16 db. Model 1204 covers the entire 1½″ x ¾″ waveguide range with a minimum isolation of 20 db. Model 1203 covers the entire 1″ x ½″ waveguide range with a minimum isolation of 30 db.

CIRCLE READER SERVICE CARD 115

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GENERAL ELECTRIC ANNOUNCES SUCCESSFUL TESTING OF 15 MEGAWATT KLYSTRON

The successful testing of the Z-3057 developmental L-band klystron at 15 megawatts peak power and 22.5 kilowatts average power output has been announced by General Electric's Power Tube Department.

One of several super-power klystrons under development at General Electric, the Z-3057 is specially designed for pulsed radar systems. It is one of the most powerful factory-produced, L-band radar klystrons ever tested.

According to General Electric engineers, the 15 megawatt operation was achieved as a result of experience gained in the development and quantity production of 10 megawatt klystrons for military applications.

Developmental work to increase the operating band width and achieve even higher power ratings on other types is now being carried out at the department's Microwave Laboratory at Palo Alto, Calif.

For additional information contact Power Tube Department, General Electric Company, Schenectady, N.Y.

CIRCLE READER SERVICE CARD 11

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NEW LITERATURE BY PRD

Two page Bulletin No. 100, available from Polytechnic Research & Development Co., Inc., Brooklyn, New York, describes a variety of microwave test equipments from the company's Pacemaker line.

ENGINEERS

STANFORD RESEARCH INSTITUTE offers unique and professionally challenging employment in the Electromagnetics Laboratory. Activities include microwave theory and techniques, theory and design of antennas, investigation of related phenomena and devices.

Attractive salaries for experienced professional personnel with degrees in Electrical Engineering or Physics to participate in research involving:

MICROWAVE

- Microwave Filters and Strip-Line Components
- Microwave Antennas
- Ferrite Devices
- Parametric Amplifiers

ANTENNA

- Basic Antenna Theory
- Antennas for Aircraft, Missiles, and Space Vehicles
- Electronically Scanned Antennas
- Microwave Antennas

For Information Contact:

Professional Employment Manager

STANFORD RESEARCH INSTITUTE

MENLO PARK • CALIFORNIA

Featured is the Standing Wave Amplifier, Type 277A, with a frequency of 1000 cps ± 2%; bandwidth selection of 15, 50 or 550-2500 cps; sensitivity of 0.1 microvolt full-scale deflection @ 15 cps bandwidth.

Specifications are included for laboratory power supply, universal power bridge, precision heterodyne frequency meter, spectrum analyzers, and klystron power supply.

An attached business reply card will enable the reader to obtain the new 160-page PRD Microwave Catalog.

Copies of Bulletin No. 100 can be obtained by writing Polytechnic Research & Development Co., Inc., 202 Tillary Street, Brooklyn 1, N.Y.

CIRCLE READER SERVICE CARD 117

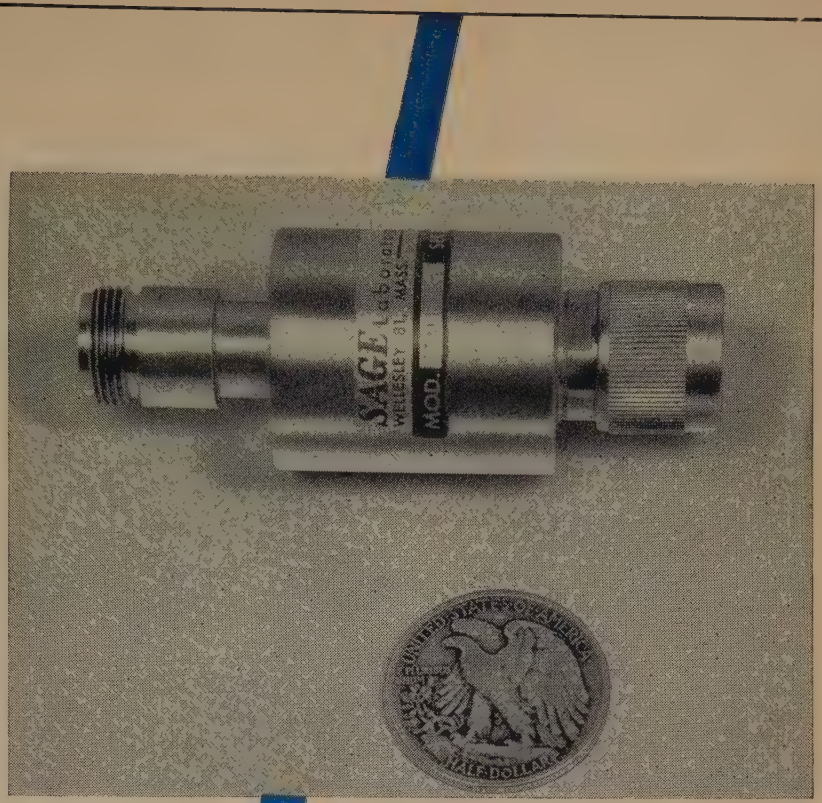
Persons . . . . . Places

LAKIN APPOINTED BY I-T-E AS SALES REPRESENTATIVE ON HIGH-POWER WAVEGUIDE

G. Alan Lakin has been appointed sales representative of Engineering Products Section, Special Products Division of I-T-E Circuit Breaker Company, Philadelphia.

He will handle sales and application engineering of high-power waveguide and waveguide components. Through its Special Products Division, I-T-E is a major supplier of large waveguide and antenna systems for commercial and military use.

Before joining I-T-E, Lakin was a sales engineer for Prodelin, Inc., antenna systems and transmission line manufacturers of Kearny, New Jersey. Prior to that he worked as a quality control engineer for the Elec-



SAGE

The SAGE 305 Coaxial Rotary Joint operates over the frequency range from DC to 12,400 mc. The maximum VSWR over the band is less than 1.25. Up to 5,000 mc, the VSWR is approximately 1.1 or less. The unit is capable of continuous duty at 500 RPM and intermittent duty at 1,000 RPM. Insertion loss is less than .1 DB. Wow is negligible. Price is $100.00.

Also available is the Sage 305-W which is a weatherized version of the 305. Price is $115.00.

Delivery in small quantities for either type is from stock.

TELEPHONE: CEDAR 5-4760
TWX: WELLESLEY MASS. 1136

CIRCLE READER SERVICE CARD 17

SAGE laboratories, inc.
159 LINDEN STREET WELLESLEY 81, MASS.

tric Storage Battery Company, Philadelphia.

He served as a Lieutenant in the U.S. Air Force for five years during which time he was an electronic countermeasures officer at the Rome Air Development Center, New York, and in the Far East.

Lakin attended Muhlenberg College, Allentown, Pa., where he was graduated in 1949 with a bachelor's degree in natural science. He is a member of the Institute of Radio Engineers.

Lakin is married, has two children and lives in Merchantville, New Jersey.

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ROBERT S. GORDON NAMED DIRECTOR OF ELECTRONICS RESEARCH AND DEVELOPMENT BY GORHAM

Robert S. Gordon has been appointed director of a new department of research and development in the Electronics Division of Gorham Manufacturing Company, Wilbur H. Norton, president, announced this week.

Mr. Gordon joined the Gorham staff in 1958 after holding a position as chief engineer of the Production Research Corporation, where he supervised the engineering and technical staff in research and development programs in communication systems, antennas, and electronic and optical instruments.

He was previously associated with the Bendix Aviation Corporation and the Army Signal Corps as well as the New York University Research Division, where he participated in Air Force geophysical research programs on high altitude phenomena.

A graduate of New York University, he has engaged in advanced studies in mathematics and electrical and mechanical engineering at Rutgers and New York University.

IMPORTANT! TO OUR READERS

Due to the increasing amount of mail received, many companies are now requesting their employees to have all personal mail, including publications, delivered to their home addresses.

Incomplete addresses are another problem faced by company mail rooms. In some cases mail stations, room, or code numbers are required for delivery.

We suggest that you check with company officials to determine whether the "journal" should be mailed to company or home address. We would also request that you examine the address to which we send your "journal" each month for accuracy.

In any event, please make use of the change of address portion included on the new subscription cards in each issue.

In cases where home addresses are used, please be sure to include all company information requested in order that the cards may be properly processed.

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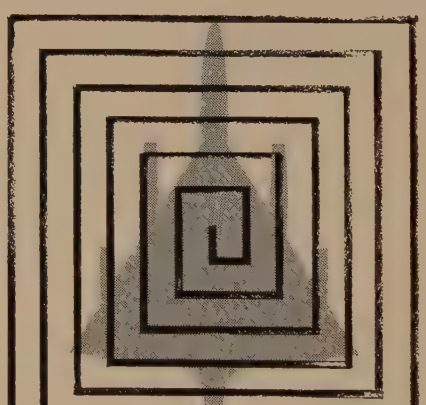
SR. ANTENNA DEVELOPMENT ENGINEERS



Melpar's expansion program has created several new positions at our Antenna and Radiation Systems Laboratory for engineers and physicists with experience in antenna design and development.

This is an outstanding opportunity to become associated with one of the Nation's leading antenna groups. We are presently working on more than thirty different types of antennas, including antenna systems for airborne equipment for missiles and supersonic aircraft, as well as ground based and submarine antenna systems. Our modern and complete facilities include a wide variety of antenna test ranges.

Location: Melpar's ultra modern main Laboratory in Falls Church, Virginia, suburban to Washington, D. C.

For details about these positions and a dynamically growing company, write to: Technical Personnel Representative

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Our good friend Marshall Pease, on another page of this issue, has a paper entitled, "When is an Engineer." In it remarks, "He (the engineer) accepts or quarrels with but cannot truly argue . . . managerial aspects." None the ss, he (the engineer) is usually keenly interested in the managerial aspects of his own firm; and, more generally, of his ıtire industry. Many the engineer who has looked up from his waveguide and file and wondered what they are up to ıw in the front office. Managerial coups or dilemmas, mergers and rumors of mergers can affect the engineer in a most timate manner.

Another group becoming more and more interested in this most dynamic of industries is the nation's financial com-unity. The phenomenal and continuing growth of the microwave industry has attracted the attention of this community, nown in a broad and general sense as "Wall Street," to a degree seldom realized. The fact of the existence of an organ-ation known as "The Electrical and Electronic Analysts Group" will be a surprise to many.

The editors trust that the following paper will give its readers an insight into the duties and responsibilities of an pert whose judgment is relied upon by many administrators in making the most weighty decisions. Let us, then, move to a rarified atmosphere seldom penetrated by the average engineer, and investigate the world of the security analyst.

THE SECURITY ANALYST

Philip Clark

Burnham and Company

The following article is about security analysts: their ıportance, their qualifications, their methods, their re-ards, and their services to you.

It wasn't too many years ago that in order to obtain at ast a fair understanding of a given company's affairs, one ıd to be a so-called "insider." Company officials would ver think of coming to Wall Street to address a group statisticians. Companies just did not provide enough in-rmation to permit an intelligent evaluation of their se-rities. Today, executives of America's largest corpora-ons come to Wall Street to make friends and influence curity analysts. They welcome analysts to their own adquarters and have arranged all expense paid tours rough their plants for large groups of analysts. Many asons are given for this change in behavior, such as the curity Act of 1933 and the Security Exchange Act of 34, the need for risk capital, a complete change in the blic relations concept of American business. Regardless the reasons, the fact is that management now en-urages meetings with security analysts.

This new relationship reflects the power and influence curity analysts have come to exercise over stock prices ıd stockholder opinions. In addition, management rec-gnizes that it is the analyst who bridges the gap between e company and the money market. The importance of e security analyst should increase. For financial institu-ons, such as Pension Funds, Mutual Funds and personal usts, continue to account for an increasing percentage of l common stock purchases, and these institutions make eir investment decisions on the basis of careful security alysis with the help of the security analyst.

he Analyst

The security analyst is the research expert employed by okerage firms, banks, and financial institutions to appraise e value of stocks and bonds and to advise their firms on vestment policy. He will generally concentrate on the ocks and bonds of a single or a few industries. He seeks to present the important facts regarding a stock or bond issue in a manner most informing and useful to an actual or potential owner. He attempts to reach dependable conclusions based upon the facts and applicable standards, as to the attractiveness of a given security at the current or assumed price.

In order for the analyst to reach dependable conclusions, he must possess a great many tools. He must understand corporate accounting, economics, the various aspects of business operations, such as marketing, production, finance, and to some degree, be able to evaluate the security market. He must understand the significance behind the abstract figures of earning statements. He must think independently and yet be able to take advantage of the comments and evaluations of others. He must be able to absorb an enormous amount of information and have the ability to assess its reliability and importance. He must concern himself with all corporate policies and have some basis for evaluating management. The success or failure of all companies depends upon the actions of management. He must be able to dig for facts, to evaluate them critically and apply his conclusions with good judgment and a fair amount of imagination. To be a good analyst, he must be curious and proud of his vocation.

The Analysts Procedure

The analyst gets his facts by reading corporate reports and statements, newspapers and trade magazines, by attending meetings of associations concerned with his industry specialty, by interviewing and getting to know corporate executives. A greater part of the analyst's time is being spent in field investigation work or the preparation of field work. The majority of analysts will always contact management of companies in which they have made or plan to make investment. There is no better way to gather reliable facts than through direct contact with management. The analyst has learned that if he does his homework properly, he will receive much better cooperation from manage-

ment which will result in a more fruitful interview. It follows that he can also be more critical of management's statements and decisions, for management will respect the analyst's criticism if it is predicated upon knowledge and understanding of management's problems.

The pre-field trip work can be quite extensive. It includes interviews with competitors, customers, suppliers and jobbers. In addition, the analyst will seek out industry statistics from trade sources and government agencies. Products affected by research and engineering development are checked out by contacting engineers specializing in similar fields in the universities and government. The analyst, in time, is apt to learn enough from the trade about the strong and weak points of the company which he is investigating so that he might become more of a managerial expert than he himself realizes.

The Electronic Analyst

The average industrial analyst has no educational background in the industry he follows. His formal training is in the field of business and banking. As an example, the analyst following the electronics industry possesses no engineering training. In spite of this, he is able to investigate and evaluate electronic equities. The reason is that he realizes that technical interpretation is not his job. It is possible and very probable that the average electronics analyst cannot define a parametric amplifier or a magnetron tube, but he does know the size of the market for these products, the low cost producer, the competition, the profit potential, and statistical projections for the increased volume in these products. It is obvious that the analyst in order to perform his job must use the tools he knows best. He must have his own frame of reference.

Services to Management

A good analyst can become a market place for the e change of ideas and needs of management.

The analyst calls on many companies of varied sizes ar establishes a number of good personal contacts within th industry. As a result, the analyst can be of real help managements. One service has already been mentione that of market sponsorship. In addition, he is in an exce lent position to advise private companies and to help pr pare them for public ownership. Other services afforded the analyst are less known but of equal importance. H sees many companies which make good acquisition can didates. Many small companies for one reason or anothe such as a need for cash, additional management help, pr duction facilities, could grow at great rates if they wer taken over by larger companies.

There are many cases where two large companies ca be put together to realize a far greater potential than eithe one separately. Often, for trade reasons or personal reason top managements cannot or will not take the initiativ for such a merger. The analyst can then be the catalyst fo these two giant corporations. Management will often con fide in an analyst of its plan to dispose of a division, an the analyst is able to suggest likely purchasers. In addi tion, the analyst sees and senses major changes in his in dustry. He sees new product development, recognizes goo managements and most importantly, discovers little com panies that could in time become big companies.

The Reward

The security analyst has a most fulfilling occupatio He learns many businesses and generally learns them wel He is afforded an opportunity to meet many interestin people. He is in a decision making position where situa tions constantly change and as a result, imagination imperative. The business is dynamic and the rewards ar fully commensurate with his ability.

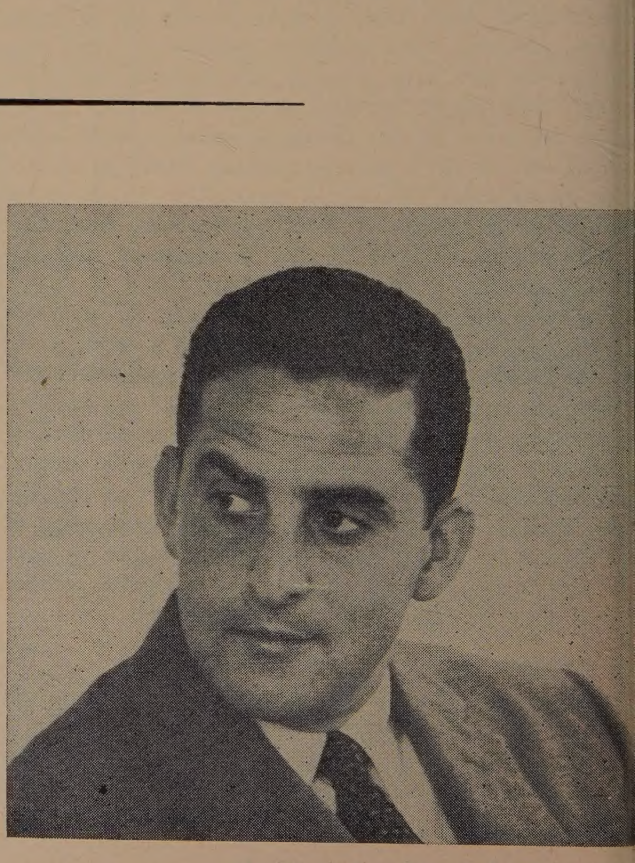
PHILIP CLARK is a Security Analyst, specializing in electronics, at Burnham and Company, a leading investment banking concern located in New York City. He has been with Burnham for seven years.

Born and raised in Chicago, Mr. Clark received his Bachelor's Degree in Business at Northwestern University.

Developing an interest in electronics while serving in the Air Force during World War II, he attended Radio, Electronic and Radar School and also taught a course in radar, specializing in IFF equipment.

Mr. Clark is a member of the Electrical and Electronic Analysts Group. This organization is made up of twenty-eight members of leading banking and institutional concerns.

Mr. Clark can fully claim to be a member of the Arts and Sciences. His wife, Irene Haas, is a commercial artist, better known for her illustrations for children's books. She has been selected for three years, as one of the ten best illustrators in the United States, by New York Times.



Sir Francis Drake Cracks a Case

One foggy day in 1588, a single ship of the Spanish Armada managed to sneak behind Drake's entire British fleet lying in the English Channel off Plymouth Hoe, and drop a 10 pounder smack in the middle of a bowling match between Sir Francis and his friend Walter Raleigh.

The new radar was caught completely by surprise. Had the IFF (Identification: Francis or Foe?) system failed? Was the operator tuned to the wrong Channel? Was there something wrong with the tubes? Drake was determined to find out. He was inside the shack in a trice, whatever that is. "Avast!" he roared at the radarman, "I must inspect those tubes!"

Drake picked up a magnetron and looked at it. "Aha!" he exclaimed. "Just as my razor-keen mind suspected!" With that, he seized the hapless operator by the throat and shook him like a tumblerful of sidecars. "I arrest you for stealing Bomac tubes and substituting these inferior substitutes, WILLIAM SHAKESPEARE!"*

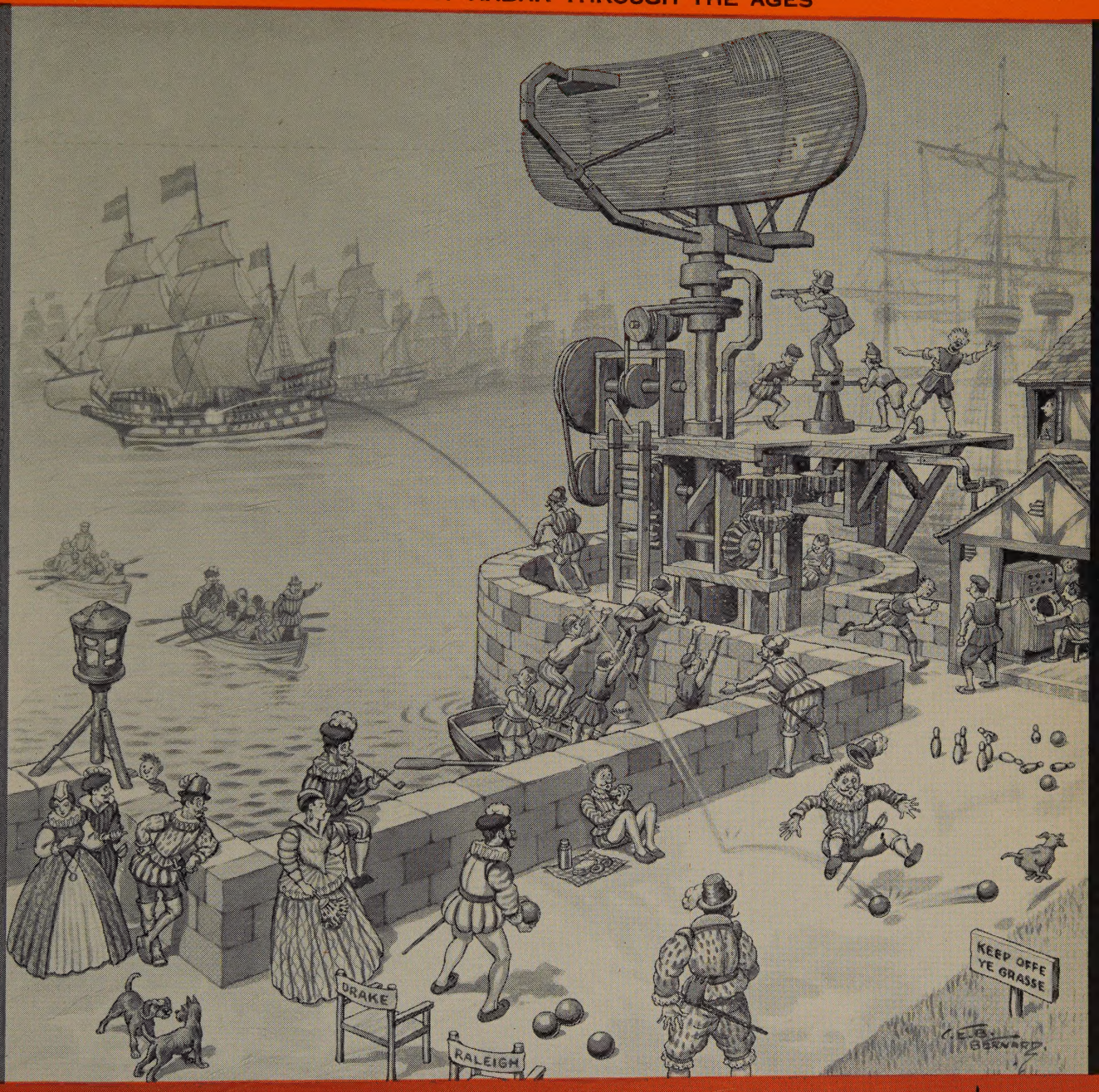
"I confess, how'd you guess?" said Shakespeare, ever the poet.

"Elementary for a razor-keen mind like mine," answered Drake. "Only you could have conceived the cunning scheme of replacing Bomac tubes with factory seconds labeled "Bethmac" as a publicity stunt for your new play — Macbeth!"

"Yours is a razor-keen mind indeed!" marveled Shakespeare as they led him away. "I haven't even written Macbeth yet!"

"Plenty of time where you're going," said Drake — and went off to bowl over the Armada.

No 13 of a series . . . BOMAC LOOKS AT RADAR THROUGH THE AGES



* *Bomac makes the finest microwave tubes and components either side of the English Channel*

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NEW 84′ KENNEDY TRACKING ANTENNA

23′ RADAR TRACKING ANTENNA

60′ TELEMETRY TRACKING ANTENNA

TOWERING 90 feet above the New England countryside at Westford, Mass., this giant 84′ tracking antenna is part of a new, long-range radar installation now studying problems in ballistics missile defense.

Equipped with an elevation-azimuth type mount designed and fabricated in cooperation with M. I. T.'s Lincoln Laboratory, the big dish can make a full 360° horizontal sweep and has a vertical rotating capability of 90°. Like all Kennedy steerable antennas, it features a light weight, aluminum dish supported by a steel pedestal mounted on a concrete base.

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